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MATHEMATICS IN AVIATION

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AIR-AGE
EDUCATION SERIES

MATHEMATICS IN AVIATION

BY

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Member of

AVIATION EDUCATION
RESEARCH GROUP

Teachers College, Columbia University

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N. L. ENGELHARDT

FOREWORD

The revolutionary influence of aviation on military strategy is now recognized by laymen as well as by military authorities. It is also apparent that the influences of aviation on civilian life are equally revolutionary and perhaps more important from the long-term viewpoint. Wide seas, dangerous reefs, precipitous mountains, frozen wastes, and jungle depths, all barriers to earthbound generations, have become features of the landscape below the global sweep of the airplane travelers in the ocean of air which is now the third dimension for an air-free people. No aspect of human ecology will remain unaltered by this new instrumentality which not only abolishes distances but also reshapes basic human geography and remolds the internal and external relationships of national and continental population groups. City, state, national, and even continental boundaries vanish or become curious anachronisms to the stratospheric travelers on great-circle routes which wheel around a planet bereft of topographical restrictions.

Our educational leaders and the schools and colleges which they represent have made it clear that they will not only contribute directly to the paramount task of winning the war by helping to train the young men who will give air supremacy to the United Nations but will also help prepare the American people for constructive living as world citizens in the air age. The War Department, the Navy Department, the Civil Aeronautics Administration, the United States Office of Education, and state and local educators are advocates of this type of education.

The AIR-AGE EDUCATION SERIES represents a major step in providing our schools with teaching materials for these purposes.

This series has two objectives. First, it seeks to provide text and teaching materials for older students in high schools in the

field of pre-flight aeronautics. Second, it seeks to provide pertinent aviation materials which may be woven into existing courses in the curricula of the secondary schools and, wherever feasible, of the elementary schools.

To name all the men, women, schools, aviation industries and authorities, publishers, representatives of colleges, universities, school systems, non-profit institutions and agencies of State and Federal Governments who made possible the AIR-AGE EDUCATION SERIES would be a difficult task. In individual books, authors have acknowledged assistance and advice from many sources. Yet the series owes its existence more particularly to a few individuals and organizations.

Special acknowledgments are due to Mr. Robert H. Hinckley, who, as Assistant Secretary of Commerce for Air, was the pioneer advocate of "air-conditioning" America; to Mr. C. I. Stanton, Administrator of the Civil Aeronautics Administration, who gave essential support to a program of aviation-education research; to Mr. Bruce Uthus of the Civil Aeronautics Administration, whose encouragement, resourcefulness, and ability so largely account for the development of the AIR-AGE EDUCATION SERIES; to Dr. John W. Studebaker, United States Commissioner of Education, who has done much to prepare American education to meet the challenge of the air age; to Professor N. L. Engelhardt, Teachers College, Columbia University, and his colleagues, who guided the development of materials reflected in this book and related teaching materials; and, finally, to Teachers College, Columbia University for the provision of indispensable office space, library, and other research facilities.

The Institute of the Aeronautical Sciences, a non-profit scientific society devoted to the advancement of aeronautics, is glad to sponsor the AIR-AGE EDUCATION SERIES in the belief that it will aid American education to eliminate the hiatus between technical aeronautical advances and popular understanding of aviation as a revolutionary world force today and tomorrow.

BEN D. WOOD
Chairman, Education Committee,
The Institute of the Aeronautical Sciences

CONTENTS

INTRODUCTION

THIS book is made up largely of problems suitable for use in connection with mathematics classes from about the sixth-grade level through the senior high school. All of the material is related directly to aviation. The book may be used as source material and as a supplementary text in many classes.

Much of the material is organized with reference to some phase of aviation rather than with reference to school grades or mathematical topics. Older arithmetic books have problems dealing with railway express. This book has a chapter devoted entirely to air express. Much of the material in this chapter is suitable for sixth-grade classes, and some of it, particularly those parts dealing with formulas, should prove helpful in algebra and general mathematics classes. So it is with many of the other chapters. The chapter dealing with fuel and oil contains problems designed to give students some understanding of the magnitude of the task of keeping planes operating all over the globe. It contains some formulas dealing with fuel and oil consumption and their application, which can be used in those grades and subjects where formulas are studied.

High-school students should find good motivation in the direct application of a geometric construction to the problem of radius of action. The importance of this problem is apparent if one considers the pilot of the plane scouting from a carrier, which, as he gets far away, becomes a moving dot that he must locate accurately on the ocean.

The graphical solution of navigation problems will give good practice in scale drawing, and alternate solutions of these problems are given for trigonometry classes. The chapter on interception contains some applications of simple geometry that should be useful when classes are working with parallel lines, trapezoids, and proportional line segments. Here we find the lines taking on new and important meaning as they become the courses of planes or ships, or the bearing lines between positions.

Probably no large proportion of high-school students will take up aeronautical engineering, yet the problems in design given in the book will make students conscious of some of the problems in planning new airplanes.

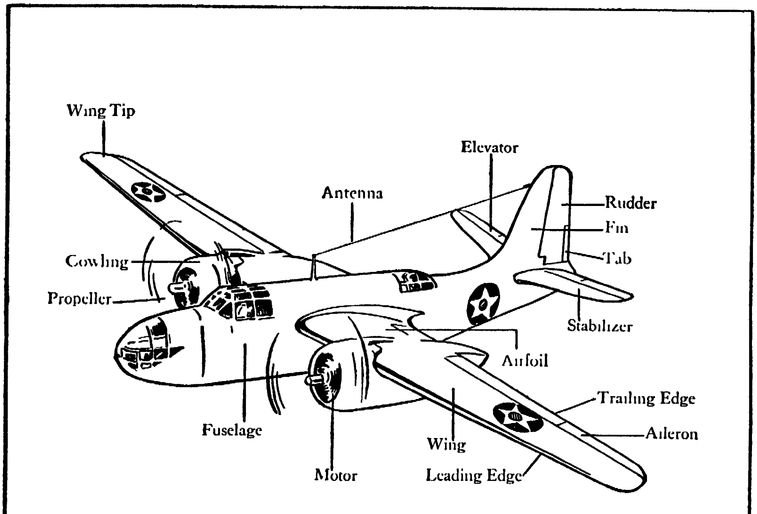
In a world brought closer together by the airplane it is important that students know something of the monetary systems of countries remote in miles but near in time. The comparatively few problems dealing with exchange are largely suggestive, as are those dealing with the metric system, which, because of its international use, is of growing importance in this country.

CHAPTER 1

TERMS FREQUENTLY USED IN AVIATION

Aileron: A movable portion of an airplane wing. It is used to give a rolling motion to the airplane.

Airfoil: Any surface such as an airplane wing, aileron, or rudder designed to obtain reaction from the air through which it moves.



Angle: Many of the terms used in connection with flight deal with angles. The most important of these terms are defined and illustrated here.

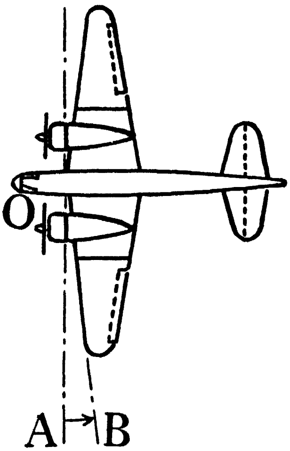
Angle of sweepback (see illustration, page 2)

$\angle AOB$ is the angle of sweepback. It is the acute angle formed by a line perpendicular to the longitudinal axis of the fuselage and the leading edge of the wing.

Angle of attack

∠AOB is the angle of attack. It is the angle between the wind stream and the chord line of the airfoil.

Angle of Sweepback



Angle of heel

The angle of heel is the angle between a horizontal plane (the water) and the lateral axis of a seaplane.

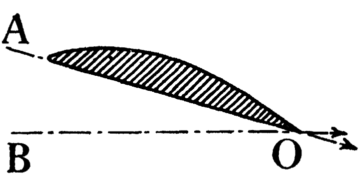
Angle of pitch

In normal flight the angle of pitch is the angle between the longitudinal axis and the direction of the relative wind.

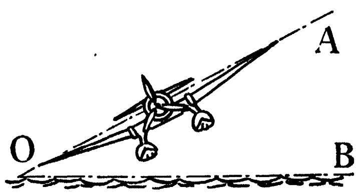
Angle of roll (or *angle of bank)*

The angle through which an aircraft must be rotated about its longitudinal axis in order to bring its lateral axis into the horizontal plane. The angle is positive when the left ride is higher than the right.

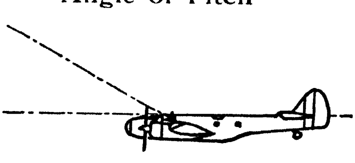
Angle of Attack



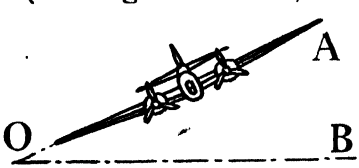
Angle of Heel



Angle of Pitch



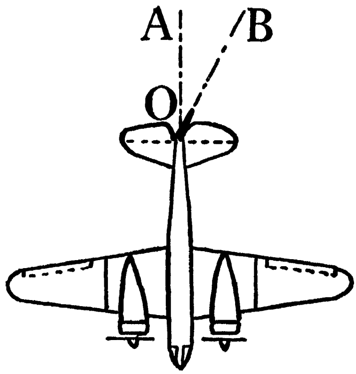
Angle of Roll
(or Angle of Bank)



Rudder angle

The acute angle between the rudder and the plane of symmetry of the aircraft. It is positive when the trailing edge has moved to the left with reference to the normal position of the pilot.

Rudder Angle



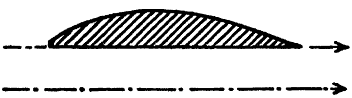
Zero-lift angle

The angle of attack of an airfoil when its lift is zero.

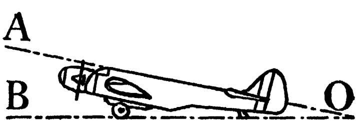
Landing angle

The acute angle between the wing chord and the horizontal when the airplane is resting on level ground in its normal position; also called *ground angle*.

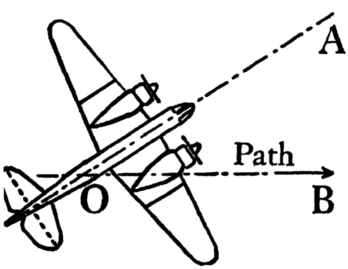
Zero-Lift Angle



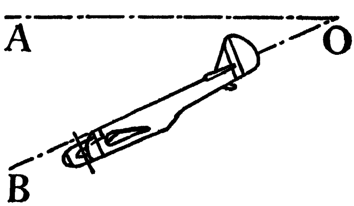
Landing Angle



Drift Angle



Gliding Angle

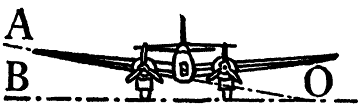


Drift angle

The horizontal angle between the longitudinal axis of an aircraft and its path relative to the ground.

Gliding angle (see illustration, page 3)
The angle between the flight path and the horizontal when plane is gliding in still air.

Dihedral Angle



Dihedral angle
The angle between the wing and the horizontal when the airplane is level and viewed from the front.

Area of wing: The total projected area of a wing including ailerons. The wing is considered as extending through the fuselage.
Aspect ratio: The ratio of the span of an airfoil to its mean (average) chord.
Bank: An airplane is said to be in a bank if it is flying with one wing lower than the other.
Camber: The rise in the curve of an airfoil section from its chord.
Ceiling: A term used to specify the altitude of the base of a cloud layer which covers over one half of the sky. The term ceiling is also used to indicate the greatest height at which a plane of any particular design is able to fly.
Center of pressure of an airfoil: That point on the chord line of an airfoil where it would be theoretically possible to consider a single force equal to all the forces acting on the airfoil.
Chord: The front-to-back or fore-and-aft dimension of an airfoil.
Cross-wing: A movement of air in a direction approximately across the line along which the airplane is traveling.
Cruising speed: The most efficient speed of an airplane.
Dope: The liquid material applied to the cloth surfaces of airplanes to produce tautness by shrinking. The dope also serves as a filler.
Drag: The resistance of the air to a body moving through it.
Duralumin: An alloy of aluminum which is used extensively for the structure of airplanes.

Elevator: A movable auxiliary airfoil which is used to give a pitching movement to the aircraft.

Factor of safety: The term usually refers to the probable minimum factor of safety, which is the ratio of the ultimate load to the probable maximum limit load.

Fin: A fixed surface attached to a part of the aircraft to secure stability.

Fuselage: The structure to which are attached the wings and the tail unit of an airplane.

Gap: The distance between the wing chords of any two adjacent wings, as in a biplane.

Gross weight: Total weight including useful load.

Lift: The total air force acting on an airplane perpendicular to the relative wind.

Lift-drag ratio: The ratio of the lift of any object to its drag.

Load:

Pay load: The part of the total load of an airplane from which income is derived.

Useful load: Everything carried in an airplane which is not a part of the plane itself.

Loading:

Power loading: The ratio of the gross weight of an airplane to the rated horsepower of the engine.

Wing loading: The number obtained by dividing the gross weight of an airplane by its wing area.

Mean Aerodynamic Chord (M.A.C.): The mean aerodynamic chord of a wing is the chord of an imaginary airfoil which has lift and drag vectors throughout flight that are the same as those of the entire wing.

Nacelle: An enclosed shelter for an engine.

Pitch: The pitch of an airplane is a change of altitude due to the rotation of an airplane about its lateral axis.

Relative wind: The flow of air around an airfoil in the same direction and with the same effect as in a given condition of flight, but with the aircraft considered stationary and the air flowing around it.

Roll: Rotation of an airplane about its longitudinal axis.

Span: The greatest distance between the tips of an airfoil, measured parallel to the lateral axis of the airplane.

Speed:

Air speed: The velocity of an airplane relative to the air.

Ground speed: The velocity of an airplane relative to the ground.

Landing speed: The slowest speed at which an airplane can maintain level flight.

Stabilizer: A fixed airfoil whose function is to lessen the pitching motion.

Stalling speed: Same, for all practical purposes, as landing speed.

Stay: A wire or other tension member.

Streamline: To shape an object so as to produce streamline flow about it.

Streamline flow: Smooth airflow.

Strut: A compression member of a truss frame; the vertical members of the wing truss of a biplane.

Tail group: The stabilizing and control surfaces at the rear of the aircraft, including stabilizer, fin, rudder, and elevator.

Taxi: To run an airplane over the ground or a seaplane on the surface of the water using its own power.

Template: A thin metal plate used as a guide or pattern in fashioning parts.

Thrust: The pull exerted by the propeller.

Tolerance: The amount of error allowed in machine work. Sometimes expressed as a per cent but often as a measurement.

Ton-mile: One ton carried a distance of one mile.

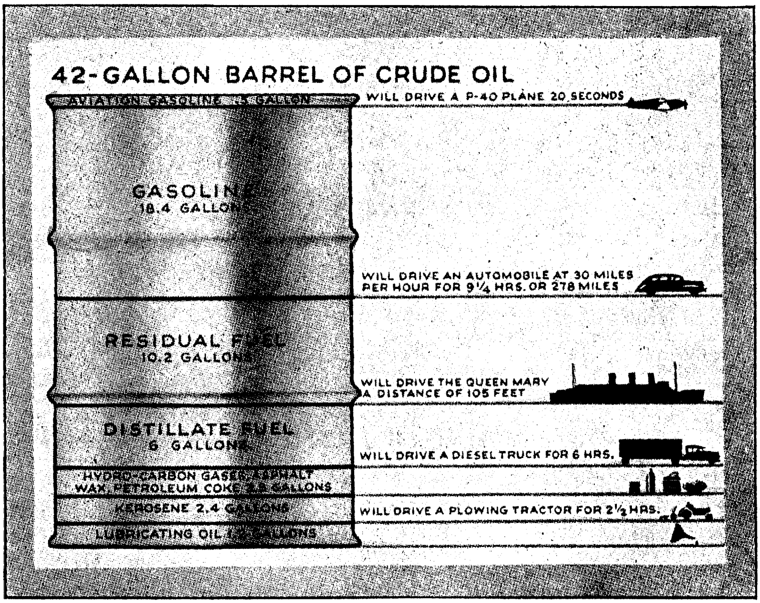
Track: The actual path over the ground or water of a plane in flight.

Trailing edge: The rearmost edge of an airfoil or propeller blade.

CHAPTER 2

FUEL AND OIL

THE problems in this chapter have to do with the important matters of production, refining, and distribution of petroleum and its products, and the use of gasoline for fuel as well as oil for the lubrication of airplane engines. Much of the information used as a basis for these problems was ob-



A pictogram showing what products are derived from a barrel of crude petroleum. From *Life,* May 18, 1942, page 64.

tained from *Life* magazine and is used by permission. The pictogram showing what products are derived from a barrel of crude petroleum is reproduced through the courtesy of *Life*.

The oil superiority of the United Nations hangs on the lines which shuttle back and forth across the map of the oceans. The

number of tanker trips per year between parts remote from each other, the number and capacity of the tankers, the ability of the railroads to move oil from the fields and refineries to the eastern seaboard, the extent and capacity of pipe lines, all are playing an important part in the carrying-on of the war.

Problems Dealing with Petroleum and Its Products

1. A tanker can make 4 round trips a year between New York and Capetown. A large ocean-going tanker carries 3,400,000 gal. of oil cargo. How many barrels at 42 gal. to a barrel can such a tanker transport to Capetown in a year?

2. This tanker has a bunker capacity of 275,000 gal. What per cent of the total oil capacity is the ship's fuel load? (Note: Bunker capacity means the capacity for fuel used to run the ship.)

3. Tankers cannot take return cargo in their tanks and have very little other cargo capacity. What is the loss in cargo-carrying weight of a tanker making 15 round trips per year between Galveston and New York if the tanker's oil-cargo capacity is 70,000 bbl.?

4. In 1940 the railroads of the United States hauled 60 bbl. of oil per day. In the spring of 1942 they were hauling 500,000 bbl. per day. The average capacity of an oil tank car is 8,200 gal. How many tank cars are required to haul half a million barrels per day?

5. The daily railroad volume of oil transportation given in the preceding problem is equivalent to how many tanker loads of 3,200,000 gal.?

6. The railroads estimated they could carry 200,000 bbl. of oil daily when called upon to replace tanker service needed for transatlantic and other long-distance hauling. Express as a per cent of the estimated capacity the hauling capacity the railroads achieved in the spring of 1942.

7. The rate of flow in an oil pipe line is 3 m.p.h. If the pipe has an inside diameter of 24 in., how many gallons flow by any given point in the line in an hour?

8. A pipe line for the delivery of oil from Texas to New York is proposed. It would, if built, have a capacity of 300,000 bbl. daily. This is equivalent to how many tank-car loads?

9. The amount of aviation gasoline in a 42-gal. barrel of crude oil is 0.5 gal. Aviation gasoline is what per cent of crude oil?

10. How many barrels of aviation gasoline can be obtained from a tanker load of 3,400,000 gal. of crude oil?

11. Aruba, an island off Venezuela, has the largest oil-refining capacity in the world. Its output is 285,000 bbl. a day. How many barrels of this will be aviation gasoline? How many days would this refinery operate at full capacity to produce a tanker load of 2,500,000-gal. capacity of aviation gasoline?

12. The world's crude-oil production is distributed as follows:

	Per cent		*Per cent*
United States	63	Russia	10
Mexico	2	Other Near East sources	4
South America	13	East Indies	3
Europe	2	All others	3

Represent this information graphically, using a single bar and dividing it proportionally to the percentages given.

13. The world's petroleum-refining capacity is distributed as follows:

	Per cent		*Per cent*
United States	65	British Isles	2
Mexico	2	Russia	9
South America	7	India	1
Continental Europe other than Russia	8	East Indies	2
		Abadan	4

Construct a graph as in problem 12.

14. From each 42-gal. barrel of crude oil 1.2 gal. of lubricating oil can be obtained. What per cent of crude is lubricating oil?

15. How many gallons of lubricating oil are there in a tanker load of 65,000 42-gal. barrels of crude oil?

16. Residual fuel is the part of the crude left after the gasoline has been removed. In a barrel of 42 gal. there are 10.2 gal. of residual fuel. What is the per cent of residual fuel?

17. How many gallons of residual fuel in a tank-car load of 8,200 gal. of crude?

18. Distillate fuel, one of the parts of crude oil, is used in Diesel-engine operation. What percentage is the distillate of the crude if there are 6 gal. of distillate in a 42-gal. barrel of crude?

19. By referring to the pictogram at the beginning of this chapter, calculate the number of barrels of residual fuel oil required to drive the *Queen Mary* 1 mi. Approximately how many barrels of residual fuel oil are required to drive this ship 3,000 mi.?

20. How much aviation gasoline is required to drive a P-40 Curtiss fighter plane 1 hr.? Refer to the pictogram.

21. A gasoline drum has a maximum capacity of 55 gal. Figuring a drum at this capacity, how many drums of gasoline do the fuel tanks (capacity 5,400 gal.) of the clipper hold?

22. A gasoline truck used for fueling the clippers has a capacity of 1,400 gal. How many trips will one truck need to make in order to put 5,000 gal. of gas in the fuel tanks of a clipper?

23. A bill for fuel amounts to $17.50. If the price is $0.246 per gal. how many gallons are bought?

24. A gasoline barge discharged 30,000 gal. of gasoline at the dock storage tanks of the Pan American Airways. How many times can the 5,400-gal. fuel tanks of one Boeing Clipper be filled from this supply?

25. The fuel capacity of the Bell P-39 Army-Pursuit-Interceptor is 140 gal. If the fuel consumption is at the rate of 56.6 gal. per hour, how many hours can this plane stay in the air?

26. The PB 2Y-2, navy patrol bomber, has a range of 5,000 mi. and a fuel capacity of 5,000 gal. Its cruising speed is 140 m.p.h. How long would it take to go 5,200 mi. at its cruising speed?

27. A certain type of plane uses $\frac{4}{5}$ gal. of gasoline per mile. How many miles can the plane travel on 30 gal. of gas? on 25 gal.? on 10 gal.?

28. The Boeing Clipper has a fuel capacity of 5,400 gal. An automobile has a fuel capacity of 17 gal. How many times as much fuel does the clipper carry as does the automobile?

29. The Canadian gallon is 5 qt. of U. S. measure. An airplane pilot took on 25 gal. of gas at a Canadian airfield. How many U. S. gallons is this?

30. A plane refueled at a Canadian airport with 32 gal. of gas. How many U. S. gallons of gas was this?

31. The range of a training plane is 450 mi. If the plane has a fuel capacity of 24 gal., what is the mileage of 1 gal. of fuel? If the cruising speed of the plane is 84 m.p.h., how much gasoline will it use in cruising 1 hr.?

32. The fuel consumption at cruising speed of a St. Louis PT-1 is 13.9 gal. per hour. Its fuel capacity is 42 gal. How many hours could this plane travel and have a reserve of 25 per cent of its fuel?

33. The Ryan St-3 has a fuel capacity of 24 gal. Its normal range is 325 mi. Find the number of miles per gallon.

34. The radius of operation of a Curtiss-Wright 21-B pursuit interceptor is 252 mi. If the radius of operation is 0.4 of the cruising range, what is the cruising range of this plane? If the Curtiss-Wright 21-B carries 100 gal. of gas, how many gallons of gas is this per mile of range?

35. Some tankers have a tank capacity of 3,000,000 gal. How many times could the clipper be fueled from a tanker if the clipper takes 5,400 gal.?

36. The fuel tanks of the Douglas DC-4 hold 2,050 gal. Fuel can be pumped into the plane's tanks through fueling intakes on the underside of the wing at the rate of 100 gal. per minute. How long will it take to refuel this plane if the tanks are empty at the start?

37. An American plane landed at a Canadian airport to be refueled. The tank was half full and 27 gal. were added to fill the tank. What is the capacity of the tank? The imperial gallon used in Canada consists of 5 U.S. qt. What is the capacity of the tank in U.S. gallons?

38. The fuel consumed by the clipper can be determined from the following table:

	Miles	*Zone*	*Fuel in gallons:*
Starting point	0	1	4,320 at start
	700	2	3,460
	1,300	3	2,660
	1,797	4	1,810

How many gallons were consumed in each zone, and what was the average rate of fuel used per mile in each zone? (To find

the number of miles in Zone 1, use the number of miles for Zone 2. For Zone 3 subtract 700 from 1,300.)

The formula $g = \dfrac{s.f.c. \times H.P. \times h}{6}$ is used to determine the number of gallons of fuel to use for a flight of a given number of hours. In this formula $h =$ hours of flight; $g =$ gallons of fuel; and *s.f.c.* = specific fuel consumption.

The *s.f.c.* is a decimal that expresses the part of a pound of fuel used every hour per horsepower of operation for any particular engine.

The 6 in the formula is the approximate weight of 1 gal. of gasoline.

1. Suppose an engine has a specific fuel consumption of 0.450. Its horsepower rating is 785. Find the total consumption of fuel for 5 hr.

2. The specific fuel consumption of the Douglas DC-4 is 0.46. Find the number of gallons required for 5 hr. flying if the horsepower rating is 4,400.

3. The specific fuel consumption of the Douglas DC-3 is 0.4819. Its horsepower rating is 2,100. Find the number of gallons required for 5 hr. of flight.

4. The specific fuel consumption of the GR 21A is 0.48. Its horsepower rating is 800. Find the number of gallons required for 3 hr. of flight.

5. An airplane engine runs 3 hr. Its horsepower rating is 450. Specific fuel consumption is 0.435. Find the total consumption.

6. Find the number of gallons of gas required by an engine of 450 horsepower for 5 hr. if the specific fuel consumption is 0.54 per horsepower hour.

7. What is the cost of this gas at 29 c. per gallon?

8. Find the total fuel consumption from the following data:

	H.P.	*s.f.c.*	*Hr.*
Wright	235	.50	4
Aeronca	40	.58	3
Franklin	130	.50	5
Allison	1150	.49	6
Lycoming	75	.50	2

A formula for finding the amount of lubricating oil of an airplane engine is:

$$g = \frac{s.o.c. \times H.P. \times H}{7.5}$$

In this formula:

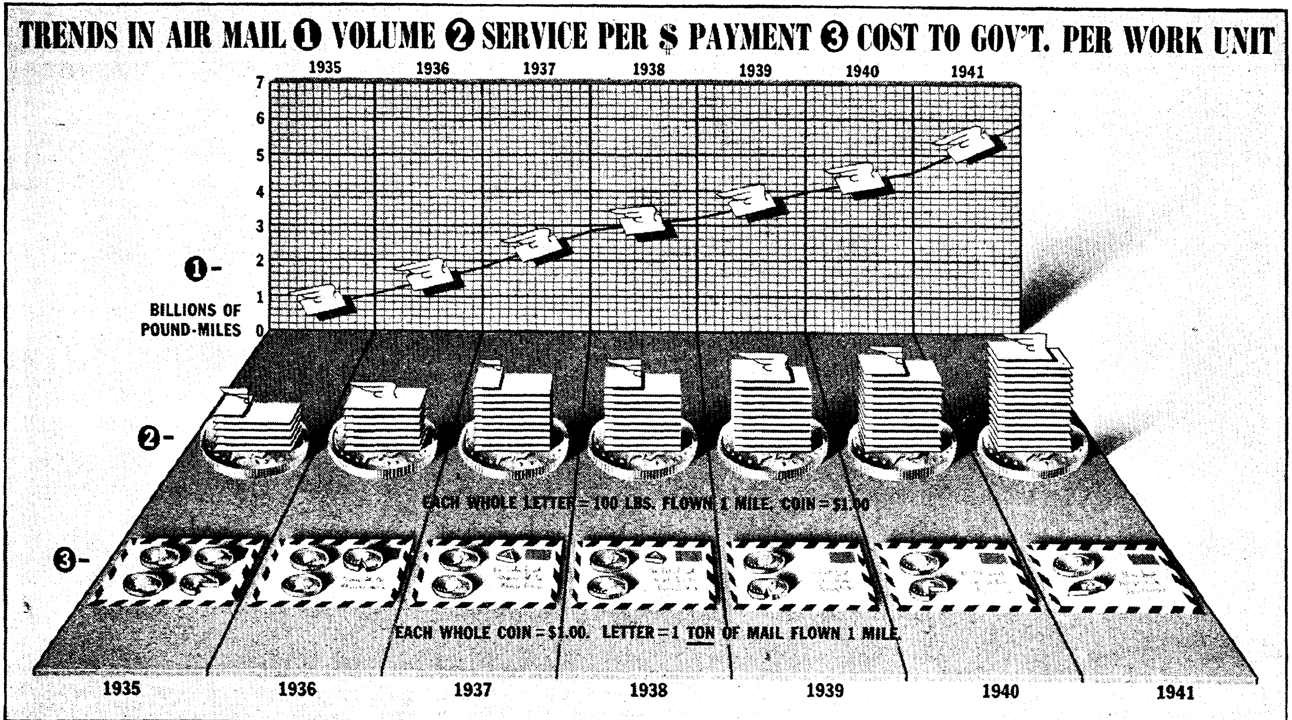
$H =$ hours of flight
$g =$ gallons of fuel
$s.o.c. =$ specific oil consumption
$H.P. =$ horsepower
$7.5 =$ the weight of 1 gal. of oil

1. Find the number of quarts of oil required using the data given here:

	H.P.	*s.o.c.*	*Hr.*
Wright	235	.025	4
Aeronca	40	.006	3
Franklin	130	.003	5
Allison	1150	.025	2
Lycoming	75	.010	6

2. Change the subject of the formula $g = \frac{s.f.c. \times H.P. \times H}{6}$ so that the number of hours can be determined directly if the number of gallons in the tank, the specific fuel consumption, and the horsepower are known.

Do the same with the formula $g = \frac{s.o.c. \times H.P. \times H}{7.5}$



Courtesy, American Airlines, Inc.

CHAPTER 3

AIR MAIL

1. The air-mail rate to Egypt from the United States is \$0.70 per half ounce or fraction thereof. If letters to Egypt have the following weights, find the cost of the postage: $\frac{3}{8}$ oz., $\frac{5}{8}$ oz., $2\frac{1}{2}$ oz., $\frac{7}{8}$ oz., and $\frac{1}{4}$ oz.

2. The postage rate from Canadian points to Colombia is \$0.25 for each quarter ounce. Find the postage cost of items having the following weights: 3 oz., $2\frac{1}{2}$ oz., $\frac{3}{32}$ oz., $\frac{1}{16}$ oz., and $\frac{5}{8}$ oz.

3. The air-mail rate between points in Canada is 6 c. for the first ounce and 5 c. for each additional ounce. What is the cost of sending packages weighing 12 oz.? 15 oz.? 20 oz.? 25 oz.?

4. All American Aviation, Inc., picks up mail at 109 points in the states of Pennsylvania, Ohio, West Virginia, Delaware, Kentucky, and New York. Between August 12, 1940, and December 23, 1941, this service handled 207,000 lb. of mail; 50,783 pickups and deliveries were made. What was the average weight of each pickup and delivery shipment?

5. If there are 32 letters to a pound on the average and if the rate is \$0.06 per letter, what is the revenue in postage on one pound of first-class air mail?

6. The ratio of air mail to first-class mail handled in Los Angeles in 1939 was 18.11%. If 9,820.6 lb. of air mail were handled daily on an average, what weight of first-class mail was handled all together?

7. Find the percentage of performance for each route from the following data. *(Copy the table. Do not write in this book.)*

FOREIGN AIR-MAIL SERVICE (1940)

	Miles Scheduled	*Miles Performed*	*Per cent of Performance*
New York to Montreal	450,993.0	429,823.0	
New York to Bermuda	81,534.0	57,610.0	
Miami to San Juan..	471,494.0	470,787.0	

8. The air-mail rate from the United States mainland to the Canal Zone is 15 c. per half ounce. What is the cost of mailing a first-class item weighing 35 oz.?

9. The air-mail rate from points in Canada to the Argentine is 35 c. for each quarter ounce. What postage is required for letters weighing 2.6 oz.? $\frac{3}{16}$ oz.? $\frac{5}{16}$ oz.? $\frac{7}{16}$ oz.?

10. During 1940 the government paid to all domestic air lines a total of $18,500,000 for carrying the mail. If this was at an average rate of 1.2 mills a pound-mile, how many pound-miles were carried? (A pound-mile is 1 lb. carried 1 mi.)

CHAPTER 4

FRACTIONS AND DECIMALS

1. The average rate of flying of a plane on a scheduled flight between two cities is 192 m.p.h. If the trip takes 5 hr. 20 min., how far is it between the two cities?

2. How many rivets will be required along a strip of wing if the strip is 211 in. in length and if the rivets are to be placed $\frac{7}{8}$ in. apart (from center to center) and if the end rivets are to be $\frac{1}{2}$ in. from the ends of the strip?

3. A stack of aircraft plywood is $9\frac{3}{16}$ in. high. How many pieces of plywood $\frac{3}{16}$ in. in thickness are there in the pile?

4. An allowance of $1\frac{1}{2}$ lb. per person per meal is made for emergency meals carried by the Pan American clippers. What is the weight of 4 emergency meals for 40 passengers and 12 crew members?

5. The approximate weight per sheet of mild carbon aircraft sheet steel is $3\frac{7}{8}$ lb. If these sheets are in standard size of 12 in. by 72 in., what is the approximate weight of 1 sq. ft.? (Express the answer as a decimal.)

Formula for the volume of a pipe is:

$$V = \pi l\,(R + r)\,(R - r)$$
$$R = \text{outside radius}$$
$$r = \text{inside radius}$$

6. Given $r = \frac{3}{8}$ in., $R = \frac{1}{2}$ in., and $l = 10$ ft., find V.

7. Find the number of cubic inches of piston displacement for a 6-cylinder engine bore $3\frac{1}{2}$ in., stroke $3\frac{3}{4}$ in. Piston displacement = area of piston $\times$ stroke $\times$ number of cylinders.

Find the piston displacement of 9-cylinder engine bore 6 in., stroke $6\frac{3}{4}$ in.

8. The cruising speed of a transport plane is 160 m.p.h. If a schedule calls for a trip between two cities to be made in 4 hr. 40 min., how far apart are the cities?

9. How many rivets will be required along the edge of a circular engine cowling if the radius of the part is 2 ft. 6 in. and the rivets are to be placed $\frac{5}{8}$ in. between centers and $\frac{3}{4}$ in. from the outer edge?

10. In the table below are given the radii of several circular disks. It is required to find the area of the circle, the area of the largest possible squares that can be cut from the disks, and the waste in each case. *(Copy the table. Do not write in this book.)*

Radius inches	*Square*	*Waste*
6		
$4\frac{1}{2}$		
$3\frac{7}{8}$		
$5\frac{1}{4}$		
$7\frac{3}{14}$		

11. To find the bearing strength of plate you must multiply the thickness of the plate by the diameter of the rivet by the bearing strength of plate expressed in pounds per square inch. Thus:

$\frac{3}{8}$ in. thickness
$\frac{1}{4}$ in. rivet
75,000 lb. per sq. in.
$\frac{3}{8} \times \frac{1}{4} \times 75{,}000 =$

Find the bearing strength of plate from this data: $\frac{5}{8}$ in. thickness, $\frac{3}{8}$ in. rivet, 80,000 lb. per sq. in.

12. The air distance between New York and Chicago is approximately 725 mi. Transport planes in 1930 had a cruising speed of 120 m.p.h. Modern planes have a cruising speed of 170 m.p.h. How much less time do you expect would be required for a trip from Chicago to New York now than in 1930?

13. If the fire-power of British machine guns mounted in planes is 2,400 rounds per minute and the planes carry an average of 300 rounds per gun, how long would it take, firing steadily with all guns, to use up the ammunition?

14. The *Hurricane* is armed with 8 Browning machine guns that fire 7,200 rounds per minute per gun. What is the total fire-power per minute? Later models of the same plane have 12 guns. What is their total fire-power per minute?

15. Outdoor hand-launched model gliders must conform to the weight rule of 1 oz. for every 50 sq. in. of wing area. Find the required weight in ounces of the models having the following wing areas: 165 sq. in.; 155 sq. in.; 140 sq. in.; and 137 sq. in.

16. If the lowest weight allowed for wing fabric is 4 oz. per square yard, what is the least weight of 25 yd. of fabric 26 in. wide if it comes up to specifications?

17. If fabric strip is 17 in. wide and if by government standards a tensile pulling load of 80 lb. per inch of fabric width is required, what is the breaking load for this strip? What is the breaking load for strips of fabric 14 in. wide? 16 in. wide?

18. A piece of duralumin 19 in. long is to be sheared into 7 equal lengths. What is the length of each piece to the nearest 32d of an inch?

19. What total length of tubing is required for the following specifications, assuming that the tubing is to be cut from one piece of stock and an allowance of $\frac{1}{8}$ in. is to be made for each cut: 3 ft. $\frac{1}{16}$ in., 2 ft. $\frac{3}{32}$ in., 1 ft. $\frac{3}{8}$ in., $\frac{5}{16}$ in.?

20. Aluminum tubing of the following lengths were used in the fuel line of a plane. What is the total weight of the line, exclusive of fittings, if the weight per foot of the tubing is 089 lb.: 12 ft. $\frac{3}{8}$ in., 3 ft. $\frac{1}{16}$ in., 5 ft. $\frac{3}{32}$ in.?

21. A piece of metal 15 in. long is to be sheared into 11 equal parts. What is the length of each piece to the nearest 64th in.?

22. If 24 cans of evaporated milk are used for each 80 gal. of coffee, and a ship's company uses 280 gal. of coffee twice a day, how many cases of evaporated milk, 4 doz. cans to a case, will be needed for coffee each day? How many cases of evaporated milk are needed for a trip of 21 days?

23. If the direct flying cost of a transport plane is figured at $54.75 per hour or at $0.35 per mile, what is regarded as the cruising speed? (Express to nearest mile per hour.)

24. A transport plane flying from La Guardia Airport to Washington has a cruising speed of 210 m.p.h. On a particular flight this plane faces a head wind of 40 m.p.h. all of the way. If the distance between the airports is 226 mi., how long does it take to complete the flight? (Express the result to the nearest minute.)

25. The operating radius of planes is usually figured at 0.4 of

the range. Given the following operating radii, find the corresponding ranges: 1,200, 750, 840, and 1,050.

26. Tubular rivets $\frac{3}{32}$ in. long and $\frac{1}{8}$ in. in diameter weigh .117 lb. per M. Approximately how many rivets are there to a pound?

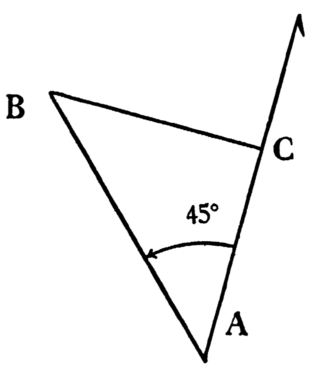
27. Supply the missing fractions in the table below, giving each fraction to the nearest 64th in. *(Copy the table. Do not write in this book.)*

U. S. STANDARD GAGE

(Stainless Steel Sheets)

Gage No.	*Decimal*	*Fraction*
1	0.281	
2	0.266	
3	0.250	
4	0.234	
5	0.219	
6	0.203	
7	0.188	
8	0.172	
9	0.156	
10	0.141	

28. A Beechcraft flew nonstop from St. Louis to Miami at an average speed of 234.097 m.p.h. in 4.635 hr. Find the distance from St. Louis to Miami.



29. If the flying cost per ton-mile is $0.0614 and the flying cost per mile is $0.507, how many tons of pay load does the plane carry? (Divide flying cost per mile by the flying cost per ton-mile.)

30. The observed angle A is 45°. An airplane carrier, following the course AC at 25 m.p.h., reaches position C 20 min. after the sight at A was taken. At C the carrier is abeam of the light. Find the ship's distance from the light at that point.

31. For each passenger on air lines 40 lb. of baggage are carried free. Each additional pound of baggage is charged for at the rate of $\frac{1}{2}$ of 1 per cent of the ticket cost. If a passenger's ticket cost $100, and his baggage weighed 41 lb., how much would he be charged for excess baggage?

32. At an average rate of $1.25 per hour, what is the labor cost of building a small airplane if 1,000 man-hours are required for its construction?

33. A pilot purchased 40 gal. of gasoline and 3 gal. of oil for his plane. The gas cost $0.21 per gallon. His bill amounted to $13.20. What was the price per quart of the oil?

34. If the flying cost is $0.426 per mile, what is the flying cost for a flight of 850 mi.?

35. If the flying cost of a plane is $0.512 per mile, what is the flying cost for 5 hr. at average rate of 164 m.p.h.?

36. A mechanic needs 420 lb. of gasoline. How many gallons does he need? If the price of gas is 28 c. per gallon, how much does he pay for gas?

37. A pilot stops at three airports and buys gas in amounts and at prices as follows: 50 gal. at 30 c., 60 gal. at 29 c., and 54 gal. at 27 c. What was his total bill for gas?

38. The charter service charge for night flying is 45 c. an airplane mile. What is the cost of a night trip of 156 airplane miles?

39. An airplane charter service charges 35 c. an airplane mile for daytime flights. What is the cost of a trip of 125 airplane miles?

40. Mr. Jones must go to a city 215 mi. distant on a speaking engagement. He finds that the only means of getting there and returning in time for conferences the next day is to charter a plane. He must go in the daytime and return at night. If the fare per air mile is 35 c. by day and 45 c. by night and the cost of waiting is $10, what will the trip cost?

41. At 37 c. an imperial gallon, how much will 23 gal. of gasoline cost at the Montreal airport? How many U.S. gallons is this, and what is the cost per U.S. gallon?

42. At 48 c. per quart how much will $1\frac{1}{2}$ gal. of lubricating oil cost at a Canadian airport? What is the cost per U.S. quart?

43. If gasoline costs 35 c. a liter in Lisbon, what is the cost

per U.S. gallon? At this price, how much will 4,250 l. of gasoline for the clipper cost?

44. Depreciation on a plane is sometimes figured at the rate of $1.00 per hour for each $1,000 of original investment. What would be the depreciation at the end of 150 hr. of flying on a plane that cost $1,450 when new? What would be the book value of the plane at the end of 350 hr.?

45. The round-trip air-line fare between Oklahoma City and Boston is $158.24. The one-way fare is $87.92. What is the saving made on a round trip by purchasing the round-trip ticket?

46. If the flying cost of a large transport plane is $0.507 per mile, what is the flying cost for a trip of 850 mi.? of 1,240 mi.?

47. If the flying cost of a large transport plane is $0.507 per mile, and the cruising speed of the plane is 170 m.p.h., what is the flying cost per hour? If a scheduled trip takes 4 hr., what is the flying cost of this trip?

48. A nautical mile is 1.152 statute, or land, miles. If a ship steams at the rate of 23 knots, how many land miles per hour does it travel? Change 46 statute miles to nautical miles.

49. What is the cost at $0.21 per gallon of enough gasoline to fill a cylindrical tank whose base is 3 ft. in diameter and whose height is 7 ft.?

50. A pilot found that his plane required 60 gal. of gas and 4 gal. of oil. If the price of gas was $0.21 per gallon and the total bill for gas and oil was $16.76, what was the price per quart of the oil? At the same rate what is the cost of 25 qt. of oil?

51. An aerial survey of 1,200 sq. mi. of forest land was completed in one season at a cost of approximately $7.50 per square mile. A ground survey of this nature would cost approximately $70 per square mile. What was the cost of the aerial survey? How much more would the ground survey have cost?

52. A round-trip fare between Boston and Cincinnati is $88.20. The one-way fare is $49. What is the saving by purchasing a round-trip ticket?

53. In flight through rough air, under clouds of the cumulus type, the temperature at the ground directly beneath will be temperature at flight level plus 5.5° F. for each 1,000 feet above

the ground. What will be the ground temperature, under the conditions given here, if the temperature at 6,500 ft. is 40° F.?

54. Modern airplane engines weigh about 1.12 times their horsepower. What are the approximate weights of engines whose horsepower ratings are 426, 550, and 780?

CHAPTER 5

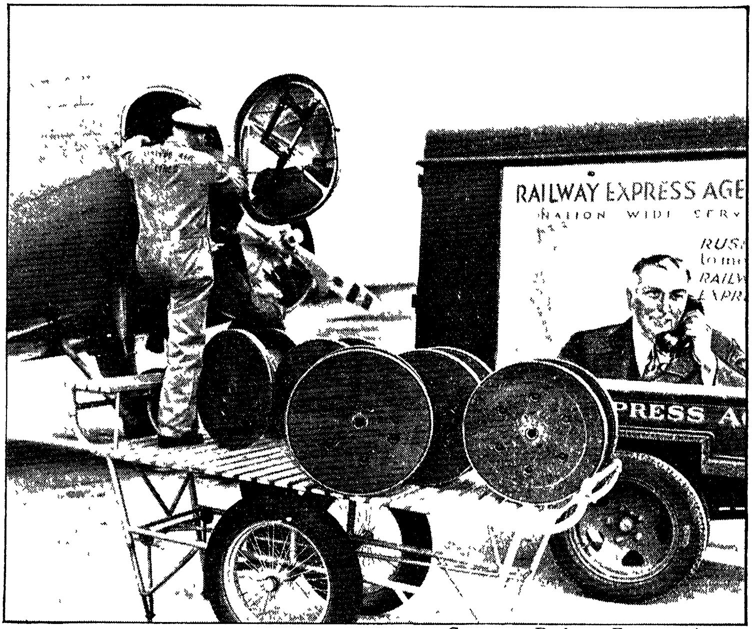
AIR EXPRESS

AT 11:00 A.M. on a Saturday morning the local telephone executive called the express superintendent to say that a complete switchboard was needed at once. The suggestion was made that the equipment be dispatched by air express from Chicago. The switchboard, consisting of 7 cases weighing 3,500 lb., was sent by special plane which left Chicago at 9:00 P.M. Saturday and arrived in Los Angeles at 10:00 A.M. the next morning.

Rose-growers in Washington, fruit-shippers in Louisiana, machinery-manufacturers in Connecticut, milliners in New York, and many others find it desirable to ship their wares by plane. The Air Express Division of the Railway Express Agency is called upon to do some unusual things, and it is playing an important part in transporting urgently needed supplies long distances. Some of the chief types of materials carried in a recent year were machinery and hardware, printed matter, store merchandise, motion-picture films, valuable papers, cut flowers, news photos, drugs, transcription records, jewelry, food, optical supplies, office supplies, and personal baggage. At the present time the Air Express Division of the Railway Express Agency serves hundreds of cities in the United States and several in Canada with direct air-express schedules. In April of this year the Air Express Division handled over a million and a half pounds of cargo, and the gross revenue from this business was almost $700,000.

Recently the newspaper press in Pine Bluff, Arkansas, broke down. The repair parts were brought by air express from Battle Creek, Michigan. Though the breakdown occurred on Saturday, the presses started rolling again at 4:00 P.M. Sunday, in time to print the Monday edition. The charge for transporting the needed parts was $53.24.

Some of the problems of this chapter are based on services that were offered before the United States entered World War II. Though most of the special commodity rates have been discontinued because of the war, the problems represent what the Air Express Division has done and will probably do again when circumstances permit.



Courtesy, Railway Express Agency

1,400 Pounds of Cable by Air Express

A pulp grinder in a Washington mill broke down, and air express saved costly delay by three-mile-a-minute delivery of heavy shipments of cable via transport plane. The General Electric Company, Seattle, was called upon for the emergency repair parts and received them from their Oakland branch in flying time on two different planes. There were nine rolls of the heavy wire and the consignment was the heaviest ever to move by air from the Oakland terminal. The shipment was handled over United Air Lines.

The formulas in this chapter were developed from the tables of rates published by the Railway Express Agency. These formulas work within the limits stated.

The rate scale numbers, which run from 1 to 24, are based on the air-line distance between points of shipment and delivery. The scale number for shipments between New York and Chi-

cago is 7. The air-line distance between the two cities is 724 mi. That is at the rate of one scale number to each hundred miles to the nearest hundred miles. The scale number between Chicago and Lincoln is 5, and the air-line distance is 484 mi. On distances over 2,400 mi. the scale number is 24. The distance from New York to Oakland is 2,610 air mi., but the scale number is 24.

Estimate the rate scale number for each of the following. *(Copy the table. Do not write in this book.)*

Cities	*Air-Line Miles*	*Rate Scale Number*
Chicago to Kansas City	405	
New York to Kansas City	1,104	
Washington to Norfolk	143	
Dallas to Houston	241	
New Orleans to Chicago	857	
New York to Boston	184	

Cost of Air Express

For a charge of $1.00 a package weighing 1 lb. or less will be carried between any two cities in the United States served directly by air express. This is the total air-express charge except for insurance. If a package is valued at more than $50 by the shipper, excess-value charges are added to the cost of transportation.

The charge for packages weighing $1\frac{1}{4}$ lb. is $1.00 for the first 5 scale numbers and 1 c. for each additional scale number except for scale number 24, for which the charge is at the regular pound rate.

A package weighing $1\frac{1}{4}$ lb. sent a distance requiring scale number 20 would be charged for as follows:

$$C = \$1.00 + (20 - 5)\,\$0.01 = \$1.15$$

A package weighing $1\frac{1}{4}$ lb. sent a distance requiring scale number 24 would have a charge determined as follows:

Formula I

$$c = 4ws \qquad \left\{\begin{aligned} w &= \text{weight in pounds} \\ c &= \text{cost in cents} \\ s &= \text{rate scale number}\end{aligned}\right.$$

$$1\tfrac{1}{4} \times 24 \times 4 = 120 \qquad w = 1\tfrac{1}{4} \text{ and } s = 24$$

$$\text{cost} = \$1.20$$

1. Find the cost of shipping a package weighing $1\frac{1}{4}$ lb. from Columbia, South Carolina, to Allentown, Pennsylvania. The rate scale number is 7.

2. Find the cost of shipping a package weighing $1\frac{1}{4}$ lb. from Warren, Pennsylvania, to Tampa, Florida. The rate scale number is 12.

3. The charge for packages weighing $1\frac{1}{2}$ lb. is \$1.00 for the first three scale numbers and 2 c. additional for each number after the third, except that regular pound rates apply for scale number 24.

Make a formula for finding the cost of shipping a $1\frac{1}{2}$-lb. package any distance calling for scale number 3 through 23.

4. The charge for packages weighing $1\frac{3}{4}$ lb. is \$1.00 for the first two scale numbers, \$1.02 for scale number 3, and 3 c. additional for each scale number from 4 through 23. The rate for scale number 24 is the regular pound rate. That is, the charge for a package weighing $1\frac{3}{4}$ lb. for scale number 3 is \$1.02. For scale number 4 it is \$1.05.

What is the charge for a package weighing $1\frac{3}{4}$ lb. for scale number 22?

5. What is the cost of sending a package of this weight a distance that requires scale number 24?

6. A 2-lb. package is carried for \$1.00 for scale numbers 1 and 2. After that the cost is 4 c. additional for each scale number through 22. Scale numbers 23 and 24 call for the regular pound charge.

Write a formula for finding the cost of sending a package weighing 2 lb. any distance from scale number 3 to scale number 22.

7. A package weighing 2 lb. is shipped from Syracuse, New York, to San Francisco, California. Find the air-express charge. The scale number is 24.

8. Find the cost of shipping a 2-lb. package from Toledo, Ohio, to Shelby, Montana. The scale number is 16.

A formula that can be used quite generally for finding the cost of shipments by air express is as follows:

FORMULA II

$$c = 100 + 4\,(sw - s - w)$$

In this formula:

$c =$ the cost in cents
$s =$ rate scale number
$w =$ the weight in pounds

The weight is to be expressed in pounds and quarter-pounds for weights up to and including 5 lb. This formula can be used for all scale numbers through 19 if the weight is 5 lb. or less.

Find the cost of sending a package weighing $3\frac{3}{4}$ lb. from Toledo, Ohio, to Roswell, New Mexico. The scale number required is 15.

$$\begin{aligned} c &= 100 + 4\,(sw - s - w) \\ &= 100 + 4\,(15 \times 3\tfrac{3}{4} - 15 - 3\tfrac{3}{4}) \\ &= 100 + 4\,(56\tfrac{1}{4} - 15 - 3\tfrac{3}{4}) \\ &= 100 + (4 \times 37\tfrac{1}{2}) \\ &= 250 \end{aligned}$$

The air express charge is $2.50.

At scale number 20 we must use the regular pound rate already described.

Apply Formula II to determine the cost of air-express ship ments, given the scale number and the weight in each case as follows: [1]

Cities	*Scale Number*	*Weight*
Boston, Mass., to Augusta, Ga.	10	$4\frac{7}{16}$ lb.
Bridgeport, Conn., to Aberdeen, S.D.	14	35 oz.
Chester, Pa., to Baton Rouge, La.	12	$2\frac{1}{2}$ lb.
Clarksburg, W.Va., to Bismarck, N.D.	12	3 lb. 5 oz.
Houston, Tex., to Abilene, Tex.	4	$2\frac{5}{16}$ lb.
Hartford, Conn., to Akron, Ohio	5	5 lb.
Gettysburg, Pa., to Atlanta, Ga.	7	4 lb. 1 oz.

[1] In the weight range up to 5 lb. the weight is determined at quarter-pounds. A weight of 2 lb. 5 oz. would be $2\frac{5}{16}$ lb. As this is $\frac{1}{16}$ more than $2\frac{1}{4}$ lb., the weight, for rate purposes, is regarded as $2\frac{1}{2}$ lb.

Cities	*Scale Number*	*Weight*
Houlton, Me., to Ann Arbor, Mich.	10	3 lb. 1 oz.
Huron, S.D., to Amarillo, Tex.	9	4 lb. 5 oz.
Garden City, Kan., to Ashland, Ky.	10	26 oz.
Weston, W.Va., to Tucson, Ariz.	19	$3\frac{1}{2}$ lb.
Wichita, Kan., to Waterville, Me.	16	$1\frac{3}{4}$ lb.
Toledo, Ohio, to Yakima, Wash.	19	2 lb. 3 oz.
York, Pa., to Winnipeg, Manitoba	15	4 lb.
Windsor, Ontario, to Tucson, Ariz.	19	2 lb. 5 oz.

Formula II can be used for finding the cost of air-express packages weighing between 5 lb. and 10 lb. In this range of weights the differences are in half-pounds instead of quarter-pounds. The formula works for scale numbers through 14 for packages weighing up to 10 lb.

Example:

Find the cost of sending a package weighing $9\frac{7}{16}$ lb. by air express from Windsor, Ontario, to Santa Fe, New Mexico. The scale number is 14; $\frac{7}{16}$ lb. is regarded as $\frac{1}{2}$ lb.; $w = 9\frac{1}{2}$.

Solution:

$$\begin{aligned} c &= 100 + 4\,(sw - s - w) \\ &= 100 + 4\,(133 - 14 - 9\tfrac{1}{2}) \\ &= 100 + 4\,(109\tfrac{1}{2}) \\ &= 538 \end{aligned}$$

The cost is $5.38.

Complete the following table. *(Copy the table. Do not write in this book.)*

Cities	*Scale Number*	*Weight*	*Cost of Air Express*
Syracuse, N.Y., to Sarasota, Fla.	13	5 lb. 6 oz.	
Tyler, Tex., to Tampa, Fla.	10	6 lb. 3 oz.	
Utica, N.Y., to Toledo, Ohio	5	9 lb. 1 oz.	
Winslow, Ariz., to Wichita, Kan.	8	8 lb. 5 oz.	
York, Pa., to Tampa, Fla.	10	7 lb.	
New York, N.Y., to New Orleans, La.	12	6 lb. 4 oz.	
Norfolk, Va., to Nashville, Tenn.	6	9 lb. 3 oz.	
Oklahoma City, Okla., to Mount Union, Pa.	12	6 lb. 2 oz.	

Cities	Scale Number	Weight	Cost of Air Express
Omaha, Neb., to New York, N.Y.	11	7 lb. 3 oz.	
Orlando, Fla., to Omaha, Neb.	13	5 lb. 11 oz.	
Omaha, Neb., to Portland, Me.	14	9 lb. 5 oz.	
Presque Isle, Me., to Natrona, Pa.	9	6 lb. 8 oz.	
Roanoke, Va., to Oklahoma City, Okla.	11	7 lb. 5 oz.	
Pitcairn, Pa., to New Orleans, La.	10	8 lb. 13 oz.	

The cost of sending shipments weighing between 10 lb. and 18 lb. and for scale numbers up to and including 6 can be found by using Formula II. Every fraction of a pound is regarded as a whole pound when the package weighs more than 10 lb.

Using Formula II, find the cost of air express in each case.

Cities	Scale Number	Weight
Waco, Tex., to Galveston, Tex.	2	15 lb.
Watertown, S.D., to Grand Forks, N.D.	5	$12\frac{1}{2}$ lb.
West Chester, Pa., to Grove City, Pa.	4	16 lb.
Williamsport, Pa., to Grafton, W.Va.	3	18 lb.
York, Pa., to Greenville, S.C.	6	14 lb. 7 oz.
Youngstown, Ohio, to Greensboro, N.C.	6	11 lb. 2 oz.
Windsor, Ontario, to Muscle Shoals, Ala.	6	13 lb. 3 oz.
Roanoke, Va., to Richmond, Va.	3	14 lb. 8 oz.
Rochester, N.Y., to Reading, Pa.	3	10 lb.
Savannah, Ga., to Richmond, Va.	4	11 lb. 8 oz.

Using Formula I, find the air-express costs of the following shipments. *(Copy the table. Do not write in this book.)*

$$(c = 4ws)$$

Scale Number	Weight pounds	Cost
11	16	
17	17	
15	15	
22	18	
23	19	

Scale Number	*Weight pounds*	*Cost*
12	20	
16	22	
18	24	
16	25	
13	21	
14	17	

1. The domestic air-express value charge is 10 c. per $100 or fraction thereof in excess of a $50 valuation which is included in the air-express rates. This excess-value charge applies to shipments weighing less than 100 lb. The declared values of shipments, each weighing less than 100 lb., are as follows: $375, $450, $110, $245, $362, $175, $225. Find the excess charge on each shipment.

2. During a test period carried on at 6 airports a comparison was made between the weight and the cubic feet of air express. During this period it was found that 1,019.5 lb. of millinery occupied 379.7 cu. ft. What was the average weight of the millinery per cubic foot?

At the same time 43,856.3 lb. of general merchandise occupied 3,439.4 cu. ft. What was the average weight of the general merchandise per cubic foot?

What is the ratio of the average weight of a cubic foot of general merchandise to average weight of a cubic foot of millinery?

Shipments of air express (one or more packages) with cubic measurements exceeding 400 cu. in. per pound will be charged for on the basis of 1 lb. per 400 cu. in.

Example:

Dimensions	*Weight*	*Basis of Assessment*
12″ × 12″ × 12″	3 lb.	1728/400 = 4 128/400 (Charge is on basis of $4\frac{1}{2}$ lb.)

3. Complete the following table. *(Copy the table. Do not write in this book.)*

Dimensions	*Weight*	*Basis of Assessment*
15″ × 16″ × 12″	5 lb.	
12″ × 15″ × 20″	10 lb.	
14″ × 16″ × 22″	$7\frac{1}{2}$ lb.	
12″ × 15″ × 14″	7 lb.	
12″ × 16″ × 8″	3 lb.	

4. Air-express regulations say that packages whose combined length and girth[1] exceed 154 in. are accepted only on condition that arrangements be made in advance for handling them on the aircraft. Are the packages whose dimensions are given below within the regulation limit? If any are in excess, how many inches are they in excess?

Package	*Length inches*	*Width inches*	*Height inches*
A	62	25	21
B	60	20	23
C	61	23	19
D	57	24	18
E	52	22	17
F	60	28	15
G	59	16	21
H	60	22	20

5. Magazines and newspapers are accepted for shipment by the air lines at 60% of the regular rates. If the regular rates for 25-lb. shipments for rate scale numbers from 5 to 10 are \$5, \$6, \$7, \$8, \$9, and \$10, find the corresponding magazine and newspaper rate.

6. The regular rate for 25 lb. of air express for rate scale number 24 is \$24. The special rate for newspapers and magazines is 60% of this. The maximum charge for newspapers is 50 c. per pound. What is the difference between 60% of the regular rate and the maximum charge?

7. The charge for collecting and remitting the amount of the C.O.D. on values from \$50 to \$80 is 52 c. What per cent

[1] Girth is the distance around an object, that is, its circumference. In a rectangular package, if $a =$ width, $b =$ height, $c =$ length, and $d =$ combined length and girth, then the formula for combined length and girth is:

$$d = 2a + 2b + c$$

is the C.O.D. service cost of the $60 value? of the $80 value?

8. Find the number of cubic feet in air-express packages having the following dimensions:

12″ × 10″ × 14″	13″ × 21″ × 18″
15″ × 16″ × 24″	14″ × 17″ × 19″
9″ × 20″ × 17″	18″ × 18″ × 19″
18″ × 18″ × 15″	20″ × 23″ × 22″
19″ × 17″ × 16″	50″ × 24″ × 23″

9. How much will it cost to send an air-express package weighing 12 lb. a distance of 1,149 mi. if the rate is $0.04 per pound for the first 149 mi. and $0.04 per pound for each additional 100 mi.? (Note: This rate does not apply to very light packages.)

10. The number of pounds of air express carried in 1940 was 11,182,561. In 1941 it was 16,823,885 lb. What was the per cent increase in 1941 business over 1940 business?

11. An air-freight company began operation in 1937. Its charges were $0.66 per shipment plus $0.09 per pound. How much did it cost to send a package weighing 55 lb.?

12. A $50-valuation limit was set. A charge of $0.10 per $100 excess value was charged. This shipment was valued at $300. What was the excess-value charge? Compare the total cost with present-day cost for rate scale number 12.

13. On January 5, 1942, air-express schedules each weekday starting from New York were as follows:

	Number of Flights Daily
New York to Chicago	30
New York to Los Angeles	20
New York to San Francisco	14
New York to Miami	5
New York to Detroit	16
New York to Cleveland	16
New York to St. Louis	8
New York to New Orleans	8
New York to Dallas	11
New York to Washington	37
New York to Boston	21

	Number of Flights Daily
New York to Seattle	22
New York to Milwaukee	24
New York to Twin Cities	24
New York to Kansas City	12

Use this information to construct a bar graph.

14. Air-express shipments in the United States:

Year	*Average Weight pounds*	*Average Charge*
1932	5.87	$3.90
1933	5.93	3.19
1934	6.32	2.99
1935	7.69	2.95
1936	8.02	2.88
1937	6.88	2.72
1938	6.60	2.68
1939	6.72	2.74
1940	7.10	2.82

Represent this information graphically, using two curves.

15. Cut flowers are raised out of doors in California and Washington and are flown to distant cities in seasons when the only flowers grown in the East are cultivated under glass. These flowers are shipped at special rates. The rate per 100 lb. from Spokane to Duluth, Minnesota, is $33.60. Shipments of less than 100 lb. are charged at pound rates proportionate to the 100-lb. rates. What is the cost of sending shipments of flowers weighing 76 lb., 55 lb., 43 lb., 27 lb., 48 lb., and 52 lb. from Spokane to Duluth?

16. Currency, gold coin, bullion, and other precious metals except silver are accepted for air-express shipment at rates ranging from $1.50 to $6.50 per $1,000 value. The average rate is $4.00 per thousand. What is the charge for sending $25,000 in currency at the average rate? $15,000 in gold at $1.50 less than the average rate?

17. Starting with Formula II, $c = 100 + 4(sw - s - w)$, find s in terms of the other letters. Making use of the new formula, find s in the following cases. *(Do not write in this book.)*

w pounds	c	s	w pounds	c	s
2	140		9	288	
$4\frac{1}{4}$	252		8	292	
5	304		$6\frac{1}{2}$	228	
$8\frac{1}{2}$	246		$1\frac{3}{4}$	138	
10	312		$1\frac{1}{2}$	114	

18. On shipments to or off air-line points in the United States the rates are the sum of the rail-express charges and the air-express charges. Find the total cost of shipping a package weighing 15 lb. from Ironton, Ohio, to Poughkeepsie, New York, if the rate scale number from Ironton to New York is 5 and the package is to be transhipped by rail from New York to Poughkeepsie at an additional charge of $0.30.

19. A special rate on sea food from Seattle and Portland to certain points as far east as Chicago is based on $33\frac{1}{3}\%$ of the regular tariff with a minimum of $1.50. The scale number for the Seattle-Chicago route is 18. Find the cost of a shipment of fresh fish weighing 12 lb. 3 oz. from Seattle to Chicago.

20. Lobsters are shipped from certain New England points to inland cities at 60% of the full rate. Find the cost of shipping lobsters from Bar Harbor, Maine, to cities requiring the following rate scale numbers from Bar Harbor:

Rate Scale Number	*Weight*
3	7 lb. 1 oz.
5	5 lb.
2	9 lb. 4 oz.
6	15 lb. 2 oz.
1	6 lb. 5 oz.

The Pan American Airways system carries express to many places in Mexico, Central and South America, the West Indies, and Alaska. The charges are based on weight and valuation, and there is an additional charge for insurance.

1. The international air-express rate from Miami to Antofagasta, Chile, is $1.26 per pound and $0.50 per $100 value.

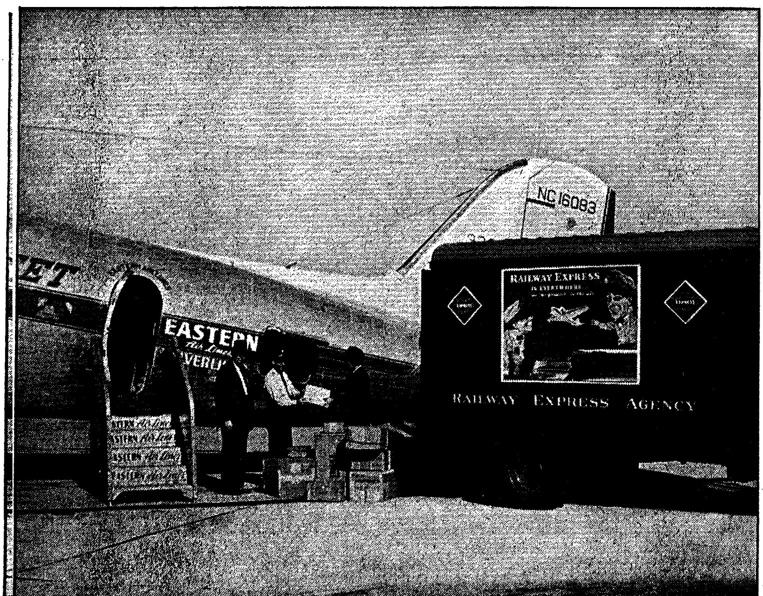
What is the cost of shipping an order of books weighing 25 lb. and having a value of $175 from Miami to Antofagasta?

2. The air-express rate from Seattle to Nome is $1.11 per pound and $0.40 per $100 valuation. What is the cost of shipping medical supplies weighing 32 lb. and valued at $315 from Seattle to Nome?

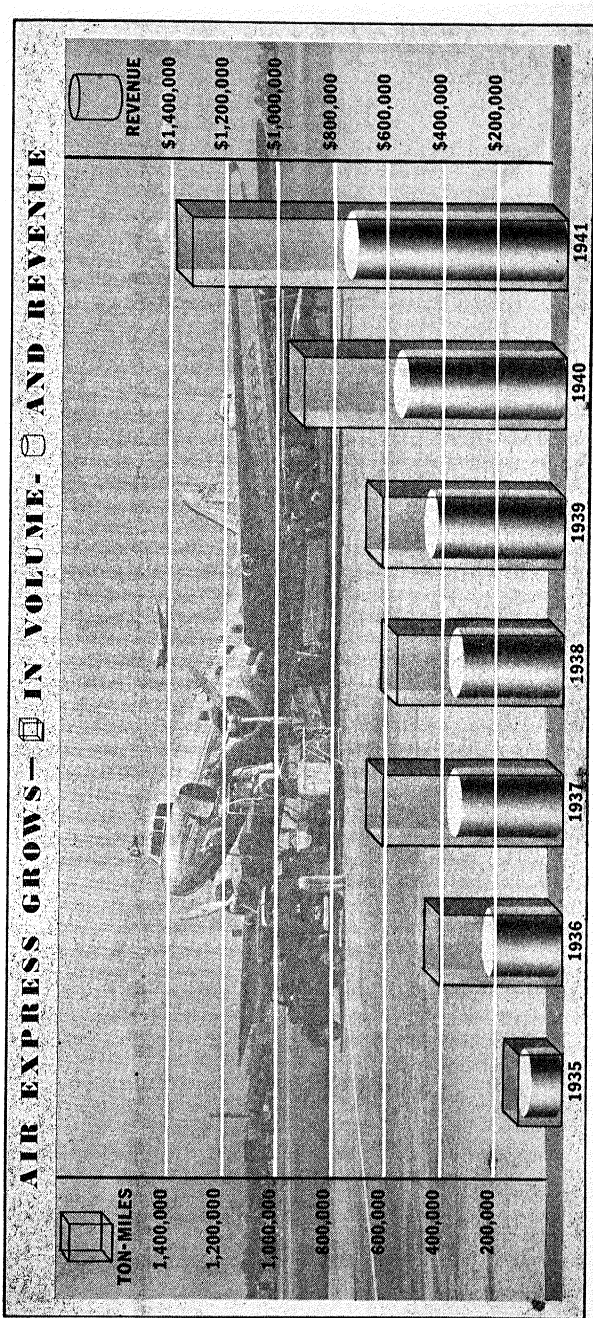
3. From the information given here, determine the cost, excluding insurance, of international air express in each case.

PAN AMERICAN CHARGES

From	*To*	*Per lb.*	*Per $100 Value*	*Wt. lb.*	*Value*
Brownsville, Tex.	Mexico City, Mex.	$0.26	$0.50	50	$275
Miami, Fla.	Port au Prince, Haiti	0.37	0.25	25	150
Miami, Fla.	Rio de Janeiro, Brazil	1.50	0.50	3	120
Miami, Fla.	San Juan, P.R.	0.53	0.40	10	30
Miami, Fla.	Santiago, Chile	1.38	0.50	15	50



Courtesy, Railway Express Agency



Courtesy, American Airlines, Inc.

4. Machine parts urgently needed in a sugar refinery were shipped via international air express from Miami to Havana. Find the total cost from the following data: \$0.20 per lb. rate; \$0.18 per \$100 value; \$0.10 insurance per \$100 value. The shipment weighed 78 lb. and was valued at \$135.

5. A shipment of watches weighing 37 lb. and valued at \$3,000 was sent from Miami to Rio de Janeiro by international air express. The unit costs are as follows: \$1.50 per lb., \$0.50 per \$100 value, and \$0.30 insurance per \$100 value. What was the international air-express charge?

6. The rates from Miami to Buenos Aires, Argentina, are: \$1.56 per lb., \$0.50 per \$100 value, and \$0.30 per \$100 insurance. Find the air-express cost of a shipment weighing 15 lb. valued at \$187.

7. Newspapers, magazines, and catalogs are accepted by Pan American Airways at half the regular rate. Find the cost of sending magazines valued at \$150 and weighing 50 lb. from Miami to Natal, Brazil, if the rates are: \$1.25 per lb., \$0.50 per \$100 value, \$0.30 per \$100 for insurance.

8. Comparison of air-express rates in 1937:

London to Paris (213 mi.)			*New York to Washington* (225 mi.)			*London to Brussels* (192 mi)		
min.	1 kg.	\$0.50	min.	1 lb.	\$1.00	min.	1 kg.	\$0.37
	11 lb.	1.22		11 lb.	1.36		11 lb.	1.00
	55 lb.	4.08		55 lb.	4.40		55 lb.	3.16

Find the difference in cost between the minimum shipments in Europe and the minimum shipments from New York to Washington. Compare the cost of the minimum shipment from London to Brussels with that of the minimum shipment from New York to Washington.

9. Pan American Express charges are assessed on weight or measurement, whichever is greater. For purposes of determining charges, 200 cu. in. = 1 lb. Determine, from the following table, which shipments are assessed on the basis of weight.

Dimensions	*Weight pounds*
10″ × 20″ × 6″	7
30″ × 20″ × 7″	25
15″ × 23″ × 10″	19
18″ × 24″ × 17″	40
18″ × 20″ × 10″	18

CHAPTER 6

AREA AND VOLUME

1. How many square inches of sheet metal are required for a fuselage part with these dimensions: 45 in. by 78 in.? How much material will be left over if this part is cut from a sheet 4 ft. by 7 ft.?

2. The main runway at the Buffalo airport is 5,000 ft. long and 150 ft. wide. What is the total surface area in acres?

3. The flight deck of a carrier is about 750 ft. long and 83 ft. wide. What is the approximate area in square feet of this deck?

4. It has been proposed that "flight strips" be built along major highways. What will the area of such a strip be if the plan is for a strip 300 ft. wide and 3,000 ft. long? if the strip is 300 ft. wide and 4,000 ft. long?

5. How many rolls of airplane floor covering will be required to cover 1,120 sq. ft. of floor surface if the material comes in 40-yd. rolls 3 in. wide?

6. A blackout paint has been developed for use in darkening windows and skylights of industrial factories. If the coverage is 800 sq. ft. per gallon, how much will be needed to cover 756,000 sq. ft.?

7. Find the number of square feet in a rectangular piece of dural used in airplane construction if the dimensions are $12\frac{1}{4}$ ft. by 9 ft.

8. Grade A fabric in 42-in. width costs $0.95 per yard. The same grade of fabric in the 60-in. width costs $1.40 per yard. Which is the cheaper per square yard?

9. Grade A fabric in 69-in. width costs $1.65 per yard. The same grade of fabric in 90-in. width costs $2.15 per yard. Which is the cheaper per square yard, and what is the difference in cost?

10. The floor surface of an airplane cabin is 106 sq. ft. Cork

linoleum on a fabric base is used for floor covering. If this material weighs $\frac{1}{4}$ lb. per square foot, what will be the total weight of the floor covering?

11. How many rolls of airplane floor covering will be required to cover 960 sq. ft. of floor surface if the material comes in 30-yd. rolls 3 in. wide?

12. The total deck space for passengers in a Pan American clipper is 748 sq. ft. If the plane is designed to accommodate 34 passengers, how many square feet are there per passenger?

13. If clear dope will cover 30 sq. ft. of surface per gallon, how many gallons will be required to cover a surface of 250 sq. ft? If pigmented dope covers 90 sq. ft. per gallon, how many gallons are required for this same area?

14. Laminated windshield plate safety glass for pilot cockpits comes in $\frac{1}{4}$-in. thickness at $3 per square foot. Figure the cost of the following order:

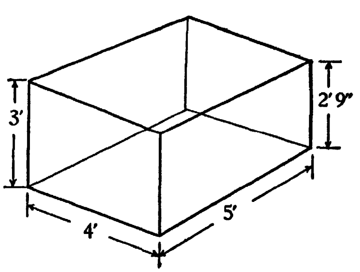
2 windshields 36″ × 18″
3 windshields 15″ × 26″
4 windshields 17″ × 23″

To the price figured above add $1.00 per square foot for cutting and seaming charges.

15. Aircraft plywood comes in 3-ply birch $\frac{3}{64}$ in. thick. Standard sheet size is 48 in. by 72 in. and the price is $7.20 per sheet. What is the price per square foot?

16. If a sheet of duralumin for use in plane construction contains 5,265 sq. in. and is $3\frac{1}{2}$ ft. wide, how long is it?

17. A baggage compartment in a plane has the dimensions shown in this diagram. What is the capacity of the compartment in cubic feet?



18. A package to be sent by air express has the following outside dimensions: 40 in. by 15 in. by 6 in. Find the number of cubic inches. If 15 packages of the same dimensions are to be shipped, what will be the total volume in cubic feet?

19. The passenger space on a clipper is 5,576 cu. ft. If the plane can accommodate 74 passengers during daytime flying,

how much space is there per passenger? Night accommodations are designed for a maximum of 34 passengers. How many cubic feet of space is this for each passenger?

20. Find the longest diagonal of a baggage compartment that is 5 ft. high at one end, 3 ft. 6 in. high at the opposite end, if the floor of the compartment is 6 ft. by 8 ft.

21. The clipper's galley is 5 ft. by $3\frac{1}{2}$ ft. by $7\frac{1}{2}$ ft. What are the floor area and the cubical contents?

22. The largest compartment on the new Boeing Clipper is $7\frac{1}{2}$ ft. high, 14 ft. wide, and 12 ft. long. There are 5 other passenger compartments, each somewhat smaller than this one. Find the area of wall (bulkheads) and ceiling (overhead) of the largest compartment. If the length is the only dimension that varies from compartment to compartment, what is the total wall and ceiling area for the remaining passenger compartments if the average length of all five is 9 ft.?

23. Find the diameter of a circle given the values 7 in. and 8 in. of the sides of the inscribed rectangle. What is the area of the circle? Find the difference between the area of the circle and that of the rectangle.

24. A cylindrical storage tank has a diameter of 4 ft. 6 in. and a height of 11 ft. *(a)* Find its volume in cubic feet. *(b)* If there are $7\frac{1}{2}$ gal. to a cubic foot, how many gallons approximately does the tank hold? *(c)* At $0.29 a gallon what is the value of a tankful of gasoline?

25. Two cylindrical storage tanks are offered for sale at the same price. One of them has the following dimensions: radius of base 6 ft. and altitude 5 ft.; the other has radius of base 5 ft. and altitude 7 ft. Which tank has the greater capacity, and what is the difference in capacity between the two?

26. A cylindrical storage tank has a diameter of 5 ft. 3 in. and a height of $9\frac{1}{2}$ ft. Find its volume in cubic feet. If there are $7\frac{1}{2}$ gal. to a cubic foot, how many gallons approximately does the tank hold?

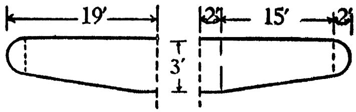
27. How many gallons can be contained in a rectangular tank 3 ft. by 4 ft. by 5 ft.?

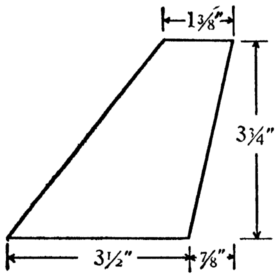
28. How high is a 72-gal. cylindrical gas tank if the area of the base is 600 sq. in.?

29. A baggage compartment in a transport plane has the

following dimensions: 6 ft. by 4 ft. 6 in. by 3 ft. 2 in. What is the capacity of the compartment in cubic feet?

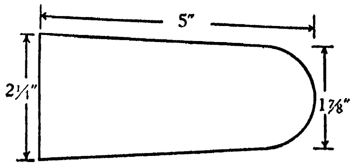
1. Using the data in the drawing, find the area of the airplane wing.

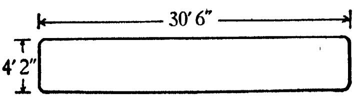




2. Find the area of the part indicated in the diagram. If this is to be cut from a rectangular strip $4\frac{1}{2}$ in. by 4 in., how much waste will there be?

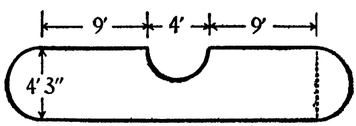
3. Find the area of this model airplane wing, using the dimensions given in the sketch.

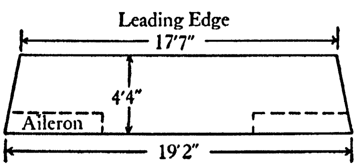




4. Find from the diagram the approximate area of the airplane wing.

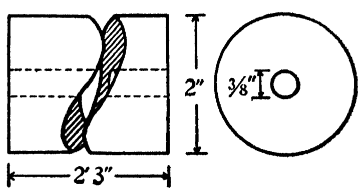
5. Find the area of the airplane wing pictured here to the nearest square foot.



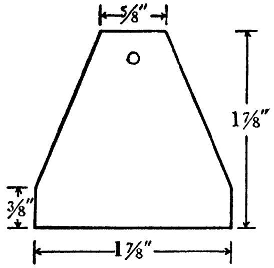


6. Find the approximate area of the airplane wing pictured here.

7. Find the volume of this tube in cubic inches. The length of the tube is 2 ft. 3 in., outside diameter is 2 in., and the hole

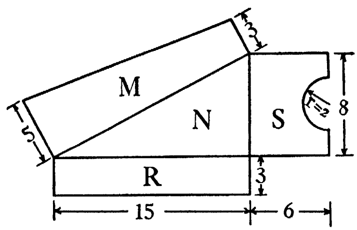


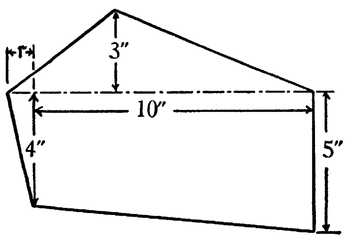
is $\frac{3}{8}$ in. in diameter. Find the area of the cross-section area of the tube.



8. Using the data in the diagram, find the area of the bracket. How much waste will there be if the bracket is cut from stock 2 in. in width?

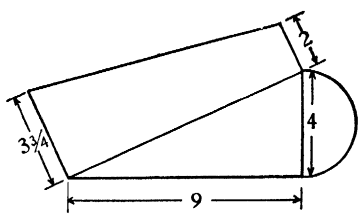
9. Find the area of the layout shown here by finding the areas of the different geometric figures and then getting their sum. Measurements shown are in inches.

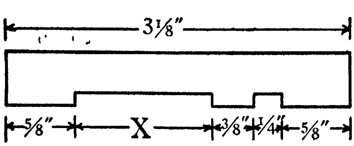




10. Find the area of the layout shown here.

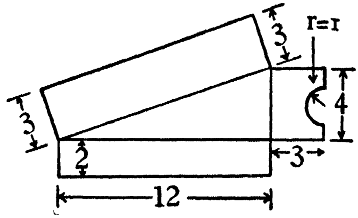
11. The weight per square foot of duralumin of 0.025-in. thickness is 0.365 lb. Find the weight of the shape pictured here. Measurements shown are in inches.





12. Find the missing dimension in the drawing at the left.

13. Find the area of the lay-out pictured.



CHAPTER 7

AIR TRAVEL

1. The one-way fare between New York and Los Angeles is $149.95. The air distance between these cities is 2,625 mi. Find the rate per mile.

2. The fare from New York to Miami is $71.75. What is the rate per mile?

3. The one-way fare between Moncton and Winnipeg is $100.20. The air distance between Moncton and Winnipeg is 1,889 mi. What is the fare per mile?

4. The round-trip fare from Calgary to Winnipeg is $87.85. The distance between Calgary and Winnipeg is 813 mi. Find the fare per mile.

5. The round-trip fare between Moncton and Winnipeg is $180.35. What is the fare per mile?

6. United Air Lines maintain a schedule of nonstop flight leaving Los Angeles at 7:00 A.M. and arriving in San Francisco at 9:00 A.M. The air distance between the two cities is 328 mi. What is the average ground speed?

7. A plane is scheduled to leave San Diego daily at 9:30 P.M. It is scheduled to arrive at Seattle, a distance of 1,214 mi. from its starting point, at 7:52 A.M. What is the rate of travel in miles per hour?

8. With 15 passengers on a trip from New York to Chicago, air distance 725 mi., what is the average passenger revenue per mile if all the passengers use full one-way tickets at $44.95 each?

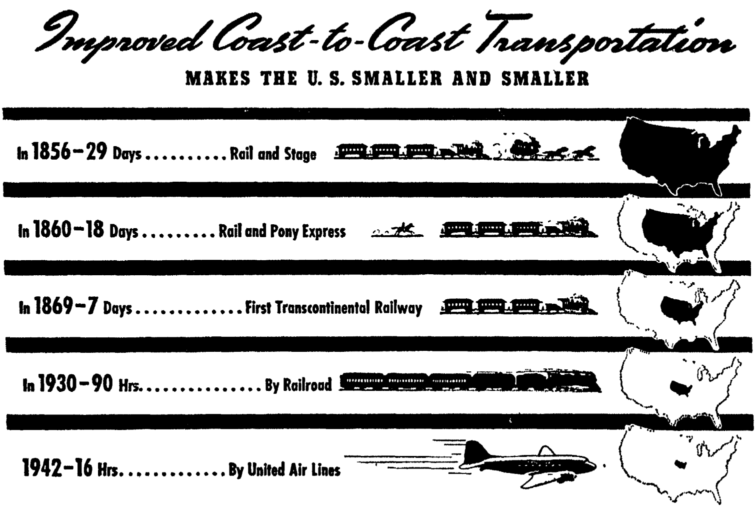
9. If a transport plane has a seating capacity of 21 and all the seats on a flight from New York to Chicago are taken by adult passengers, what is the passenger revenue if 10 of the people have one-way tickets at $44.95 each and the rest have round-trip tickets costing $80.90?

10. The air-line fare from New York to Chicago is $44.95. What is the passenger revenue received by the air line for a

flight on which there are 12 adults and 4 children at half fare?

11. The arrivals and departures in the timetable of Alaska Services are shown in U.S.A. Meridian War Time west of Greenwich. For each 15° difference in longitude there is 1 hr. difference in time. The entry for Nome gives 165° M.W.T. and that for Juneau 135° M.W.T. When it is 10:00 A.M. in Juneau what time is it in Nome?

12. A plane flying into a wind which has a velocity of 30 m.p.h. makes the trip from New York to Washington, a distance of 225 mi., in 1 hr. 45 min. How long would the trip have taken if there had been no wind?



13. An airplane going from Albany to Boston, a distance of 200 mi., made the trip from Albany to Boston in $1\frac{1}{2}$ hr. There was no wind. The return trip was made in the same length of time. The next day the trip was undertaken, but this time there was a west wind of 30 m.p.h. that continued throughout the round trip. How long did it take the plane to reach Boston and how long for the return?

14. In 1940 the air lines of the United States reported 1,041,173,558 domestic passenger-miles for which revenue was received. (A passenger-mile is 1 passenger for 1 mile.) At the reported average rate of $0.05 per passenger-mile what was the total passenger revenue for 1940?

15. On a flight from Albuquerque to Chicago all 15 seats were occupied as far as Kansas City. There 4 passengers left the plane and 3 boarded it. The fare from Albuquerque to Chicago is $64.35, from Kansas City to Chicago $21.50, and from Albuquerque to Kansas City $42.85. What passenger revenue was received for this flight if all the passengers paid full fare?

16. The four-hundredth transatlantic crossing was made by Pan American Airways in June 1941. At an average of 3,800 mi. per crossing, how many miles is this all together?

17. The Curtiss-Wright 20 has a daytime passenger capacity of 36 people. Find the total weight of 36 passengers having the following individual weights:

No. of People	*Weight of Each*	*No. of People*	*Weight of Each*
1	185	4	155
2	180	3	150
2	175	4	145
3	170	4	140
5	165	3	135
3	160	2	130

18. John, age 12; George, age 10; and their mother and father went by plane from New York to Boston. The fare one way is $11.95. What was the cost of the plane trip for the family? (Children under 12 years of age pay half fare.)

19. If the average weight of passengers on a flight of the *Atlantic Clipper* is 140 lb. and there are 40 passengers, what is the total weight of the passengers? If the average weight of crew members is 151 lb. and there are 12 men in the crew, what is the total weight of people aboard the plane?

20. Baggage-dimension limits of Douglas planes used on the TWA lines are 60 in. by 24 in. by 19 in., and on Boeing planes of the same line are 88 in. by 40 in. by 28 in. Express the difference in volumes to the nearest cubic foot.

21. The sales price of the Douglas DC-3 is $115,000. The maximum gross weight of this plane is 24,150 lb. What is the value per pound of gross weight of this plane?

22. The daily mileage of 6 round trips between Washington and Detroit via Pittsburgh is 4,824 mi. What is the airway distance between Washington and Detroit via Pittsburgh?

23. The daily mileage of 12 round trips between New York

and Washington is 4,136 mi. What is the airway distance between New York and Washington?

24. The daily mileage of 4 round trips between New York and Miami is 9,632 mi. What is the airway distance between these cities?

25. Seven daily round trips are scheduled by Eastern Air Lines between New York and Atlanta. If the total mileage of these trips is 11,130 mi., what is the airway distance between these cities?

26. In June 1940 the seating capacity of the air-transport fleet of the United States was equivalent to that of 5 medium-sized passenger trains. If the standard passenger coach seats 80 passengers, how many coaches would be required for a total air-transport seating capacity of 3,877?

27. The number of passenger miles flown in November 1941 was 106,617,815. The number of passengers during this month was 301,878. What was the average mileage per passenger? If the average price per mile was $0.05, what was the average price per passenger?

28. The average passenger flight is 600 mi. and the average fare is $30. What is the average rate per mile?

29. Before a person can become a first pilot of a transport plane he must have a record of 1,500 hr. of flight. If we assume 140 m.p.h. as the average rate of flight, how many miles must the aviator fly to qualify for a first-pilot position?

30. On January 6, 1942, the Pan American *Pacific Clipper* completed a trip from Auckland, New Zealand, to New York. The plane flew 31,500 mi. The time in the air was $209\frac{1}{2}$ hr. What was the average ground speed?

31. On its great trip from Auckland to New York the *Pacific Clipper* flew over 6,026 mi. of desert and jungle country. What per cent of the voyage was over desert or jungle?

32. The plane's longest nonstop leg was between West Africa and the northeast coast of South America. This distance was 3,583 mi. At the average rate worked out in problem 30 what was the time required for this leg?

33. A plane on the Trans-Canada Air Lines is scheduled to leave Vancouver at 6:00 A.M. (P.S.T.) and arrive in Lethbridge at 9:30 A.M. (M.S.T.). What is the ground rate per mile if Lethbridge is 469 mi. from Vancouver?

34. A plane scheduled to leave Fairbanks at 9:00 A.M. is to arrive in Nome at 11:25. The Fairbanks time is 1:50 M.W.T. and the Nome time is 1:65 M.W.T. The distance between the cities is 540 mi. Find the average ground rate of the scheduled flight.

35. The cost of operating the Douglas DC-3 is $55.95 per hour. At 167 m.p.h., what is the cost of operation per mile?

CHAPTER 8

GRAPHS

1. Below are indicated the number of miles flown per accident in the period 1935–1940. Represent graphically:

1935	55,871
1936	54,959
1937	53,832
1938	68,735
1939	81,778
1940	76,610

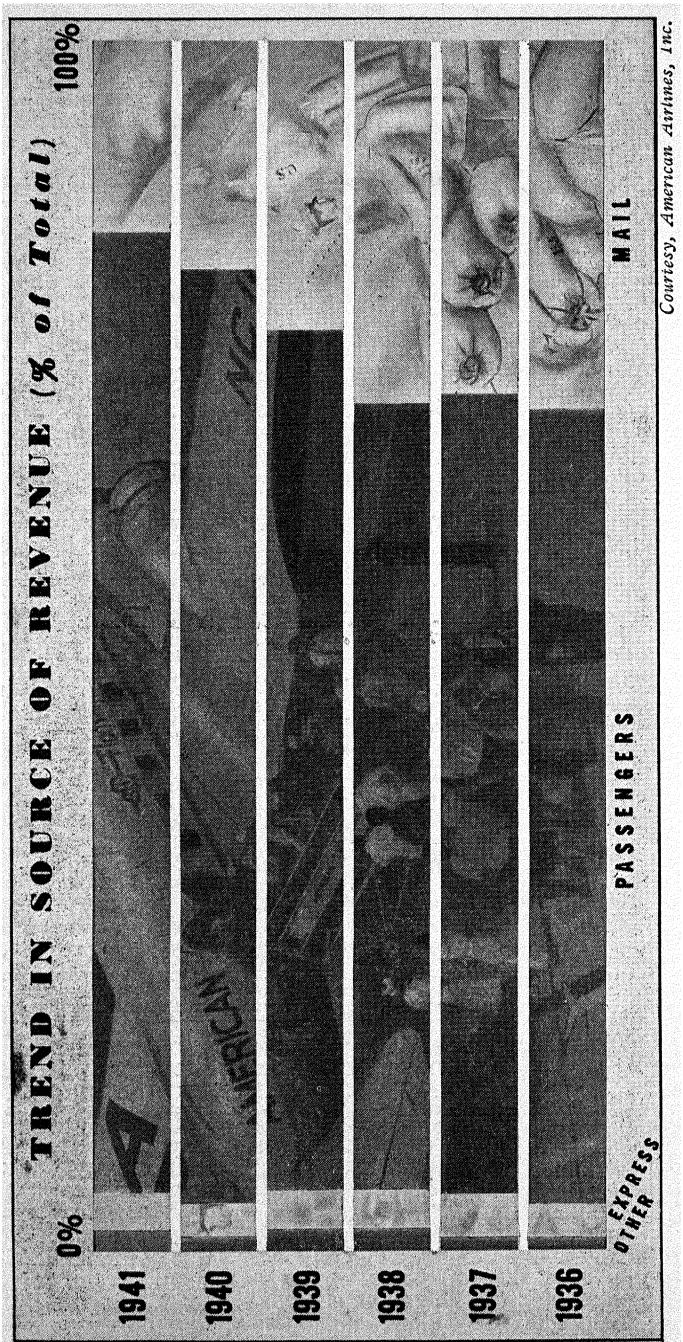
2. Following are the numbers of passengers carried by 5 prominent air lines during November 1941:

A. A.	99,632
Eastern	46,812
U. A. L.	41,967
T. W. A.	34,750
P. C. A.	26,783
All other	
Total	301,878

Make a bar graph using these figures. What per cent of the number of passengers carried were transported by the five for whom figures are given?

3. Make a temperature chart using the following data:

Altitude of Plane	*Temperature of Air (Fahrenheit)*
8,000	46°
7,000	49°
6,000	53°



Courtesy, American Airlines, Inc.

Altitude of Plane	*Temperature of Air (Fahrenheit)*
5,000	56°
4,000	59°
3,000	60°
2,000	65°
1,000	70°
Ground	71°

4. Construct a divided bar graph to illustrate the division of weight in a transport plane.

Empty weight	10,400 lb.
Pay load	4,250 lb.
Useful load	6,600 lb.

(Note: Pay load is part of the useful load.)

5. The rate of climb of a Boeing Stratoliner with 4 engines is 1,200 ft. per minute, with 3 engines 600 ft. per minute, and with 2 engines 113 ft. per minute. Construct a graph representing these three rates of climb and measure the climbing angle for each rate.

6. Plot a graph for the formula $s = \frac{1}{2}gt^2$. Let t have values 1 to 7. Find s when $t = 3$. Find s when $t = 2\frac{1}{2}$.

7. Millions of passenger miles per air-line fatality 1931-1940 are given below.

	Passenger Miles millions
1931	4.3
1932	6.7
1933	21.6
1934	11.1
1935	20.9
1936	9.9
1937	11.9
1938	22.3
1939	83.8
1940	32.8

Use the data here to construct a bar graph. What was the "safest" year?

8. Construct a broken-line graph showing the number of

airplanes manufactured in the United States for the period 1935–1940, using the following figures:

1935	1,691
1936	3,010
1937	3,773
1938	2,698*
1939	4,934*
1940	9,910*

9. From the information given below make a broken-line graph showing the relation between miles flown and cost per mile of planes used in carrying air mail for a period of 9 mo.

Miles Flown	*Cost per Mile*
37,000	$0.82
40,000	0.76
45,000	0.70
50,000	0.65
55,000	0.62
60,000	0.58
65,000	0.55
76,000	0.525
75,000	0.50

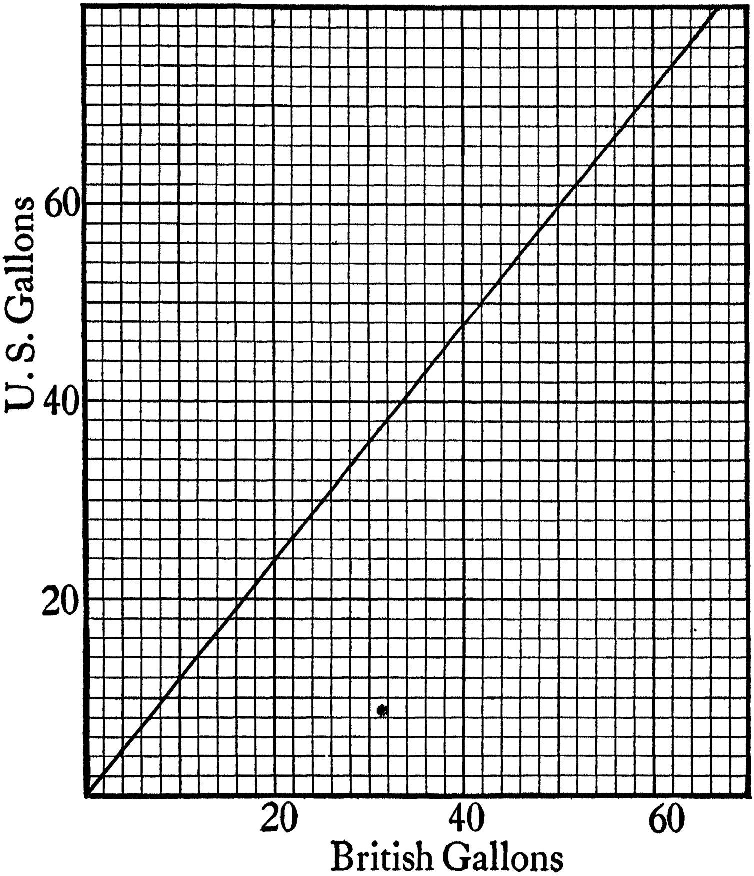
10. Using the following information about an airplane, make a circle graph.

Gross weight	43,000
Empty weight	23,550
Useful load	19,450
Fuel, oil, crew	2,930
Pay load	16,520

11. Use the following table to make a bar graph of horsepower of these fighter planes:

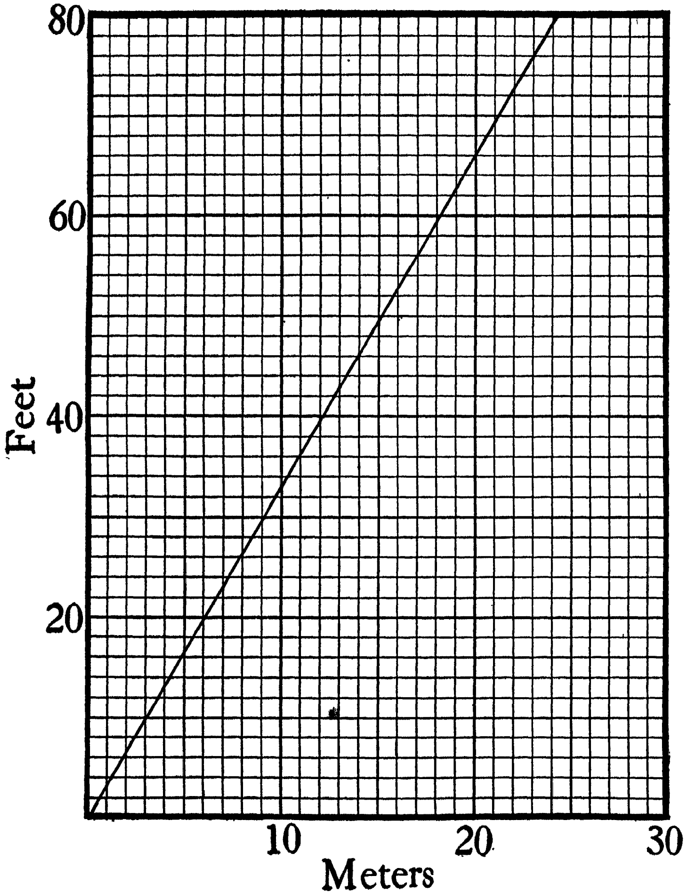
Plane	*Engine Horsepower*	
Curtiss P-40	950	Tomahawk in R.A.F.
Curtiss P 40 D	1,050	Kittyhawk
Bell P 39	1,050	Airacobra
Brewster	1,200	Buffalo
Republic P-43	1,100	Lancer
Republic P-47	2,000	Thunderbolt

* Does not include aircraft produced for United States military services.



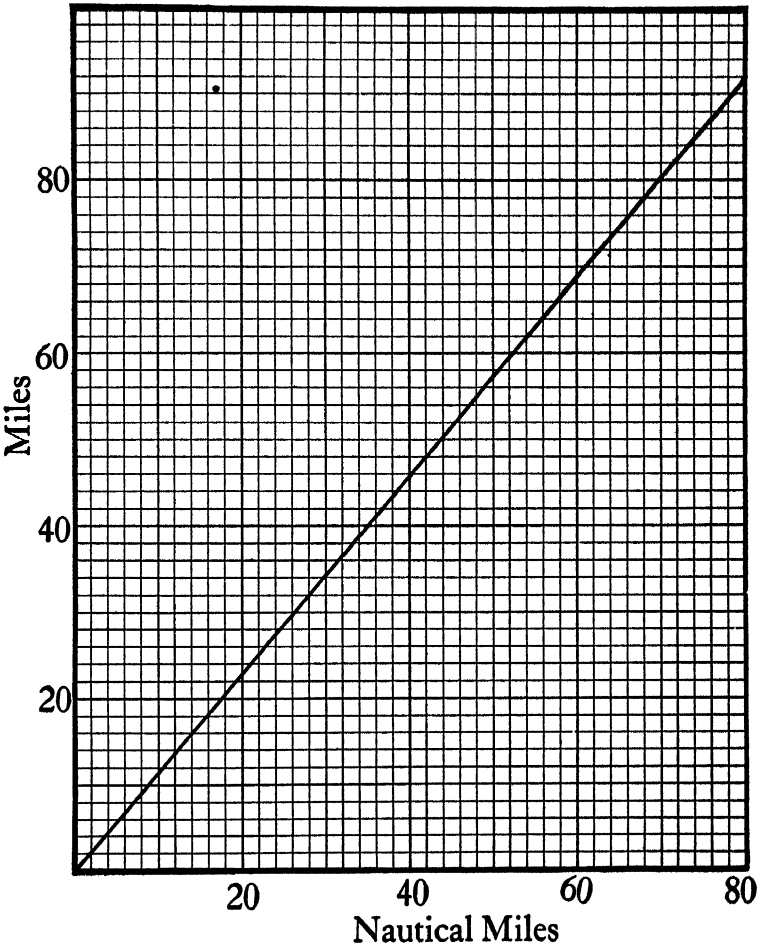
12. Using the graph for converting U.S. to British gallons, complete the following table. *(Copy the table. Do not write in this book.)*

U.S. Gallons	*British Gallons*
5	
	26
65	
	21
55	
40	
	35.5



13. Using the graph for converting feet to meters, complete the following table. *(Copy the table. Do not write in this book.)*

Feet	*Meters*
36	
70	
	10
	15
25	
16	
3	



14. Complete the following table by using the graph for changing miles to nautical miles. *(Copy the table. Do not write in this book.)*

Miles	*Nautical Miles*
20	
30	
70	
	24
	35

15. Airplane fabric comes in the following widths at the price per yard indicated. Make a graph showing the relationship between width of fabric and price per yard. (Two-line graph.)

Width inches	*Price per Yard*
36	$0.75
42	0.95
60	1.40
69	1.65
90	2.15

16. Construct a bar graph showing the number of private airplanes in operation in the United States for the period 1935–1940, using the following figures:

Year	*Number of Private Airplanes*
1935	8,613
1936	8,849
1937	10,446
1938	10,718
1939	12,274
1940	16,903

17. From the table below make a bar graph to illustrate the record-breaking altitudes reached by planes and balloons. (Use vertical bars.)

Year	*Altitude*	*Flyer*	*Country*
1911	12,959	Garros	France
1918	19,270	Perreyon	France
1921	37,140	Macready	United States
1929	39,140	Soucek	United States
1930	43,166	Soucek	United States
1934	47,353	Donati	Italy
1937	53,937	Adam	England
1931	51,775	Piccard	Belgium Balloon
1933	61,237	Settle and Fordney	United States Balloon
1935	72,395	Stevens and Anderson	United States Balloon

18. From the following data make a bar graph showing the lengths in miles of record-breaking nonstop flights.

Year	*Miles*		*Year*	*Miles*	
1903	1	United States	1926	3,313	France
1909	32	France	1927	3,610	United States
1910	143	United States	1927	3,905	United States
1911	250	France	1928	4,450	Italy
1913	542	France	1931	5,011	United States
1919	1,890	England	1933	5,341	England
1923	2,116	United States	1936	6,150	England
1926	2,930	France	1937	6,296	Soviet Union

19. The following table gives distances of visibility for objects of various elevations above sea level. Using the information given, construct a broken-line graph.

Height in Feet	*Nautical Miles*
110	12.0
120	12.6
130	13.1
140	13.6
150	14.1
200	16.2
250	18.2
300	19.9
350	21.5

20. Construct a bar graph using this information:

1,035	approved municipal airports
795	commercial airports
282	intermediate fields
74	army fields
27	navy fields
41	miscellaneous government fields
23	private fields

21. Make a pictogram representing the number of days required to cross the Atlantic by ship and by clipper if the number of days for each crossing at a given period was:

1492	40 days	Santa Maria
1850	18 days	Clipper Ship
1874	11 days	Great Eastern
1934	4 days	Normandie
1940	25 hrs. 1 min.	Atlantic Clipper

22. Make a circle graph using the following information:

Distribution of Plane Weight	*Per cent*
Useful load, pilot, fuel, etc.	24.5
Power plant, fuel, cooling system	35.2
Wing	12.1
Tail group	2.7
Landing gear	5.2
Fuselage	10.7
Nacelles	9.6

23. Make two circle graphs using this information about common types of airplane accidents:

	Private Flying per cent	*Scheduled Domestic Air-Line Flying per cent*
Take-off	26	31
Collision	5	9
Forced landing	15	12
Landing	38	36
Stalls and spins	11	1
Other types	5	11

24. Make a bar graph using these data on weights of materials in pounds per cubic foot.

	Pounds per cubic foot
Balsa wood	7
Spruce	27
Dural	175
Steel	480

25. Construct a bar graph showing the increase in mechanical and ground-crew employees between 1935 and 1940.

Year	*Employees*
1935	2,618
1936	2,874
1937	3,280
1938	3,415
1939	4,006
1940	5,409

26. Construct a line graph showing the temperature at different altitudes on a particular day.

Altitude of Plane	*Temperature of Air (Fahrenheit)*
8,000	57°
7,000	60°
6,000	63°
5,000	65°
4,000	70°
3,000	73°
2,000	75°
1,000	80°
ground	80°

27. The average number of available seats per plane in scheduled air-carrier operation between 1935 and 1940 was as follows:

Year	*Seats*
1935	10.34
1936	10.67
1937	12.53
1938	13.63
1939	14.63
1940	16.52

Represent the data with a bar graph.

28. The following table gives the amount of money appropriated each year from 1936 through 1942 for army aviation. Construct a bar graph using these data.

Year	*Appropriation for Army Aviation*
1936	$ 45,383,400
1937	59,397,714
1938	58,618,406
1939	70,556,972
1940	186,252,244
1941	2,173,090,961
1942	4,341,735,322

29. Using formula: Ground speed m.p.h. $= \dfrac{\text{distance} \times 60}{\text{minutes}}$, construct a graph to give the ground speed over nine 10-mi. track sections (portion of the route over which flight is made) for each of the following periods of time:

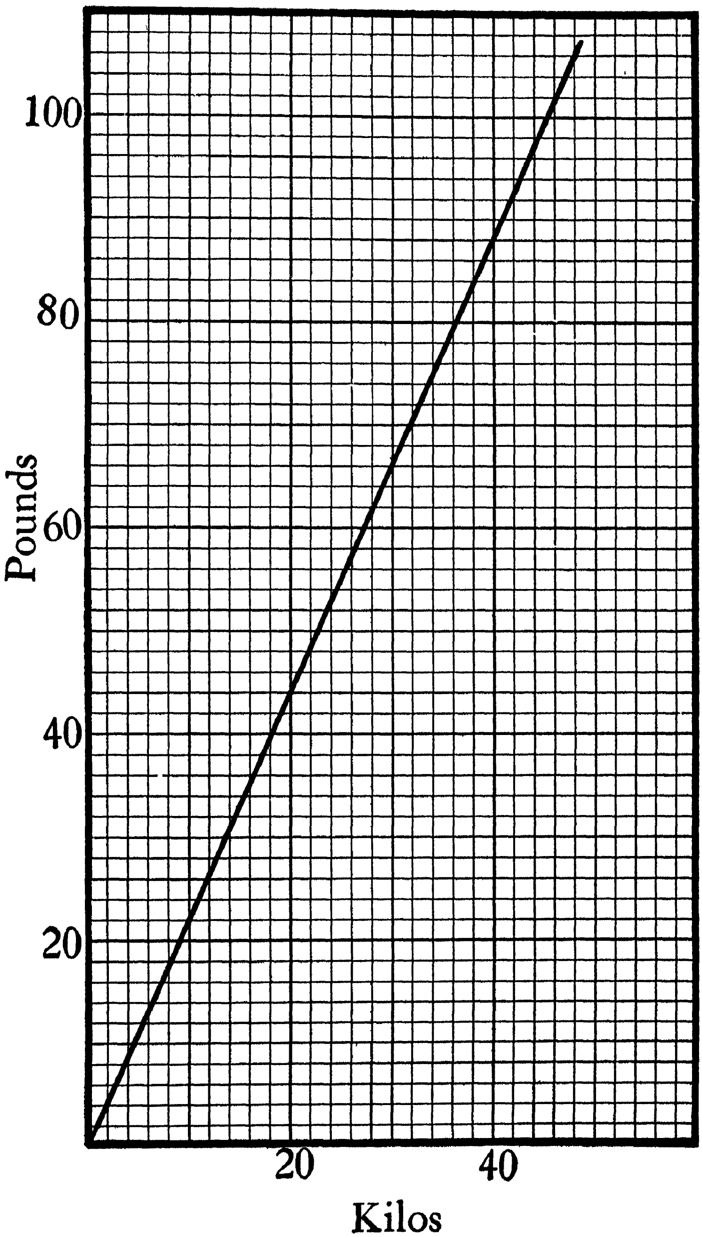
5 min. 18 sec.	4 min. 48 sec.
5 min. 40 sec.	3 min. 18 sec.
5 min. 30 sec.	3 min. 48 sec.
5 min. 12 sec.	3 min. 40 sec.
5 min. 0 sec.	

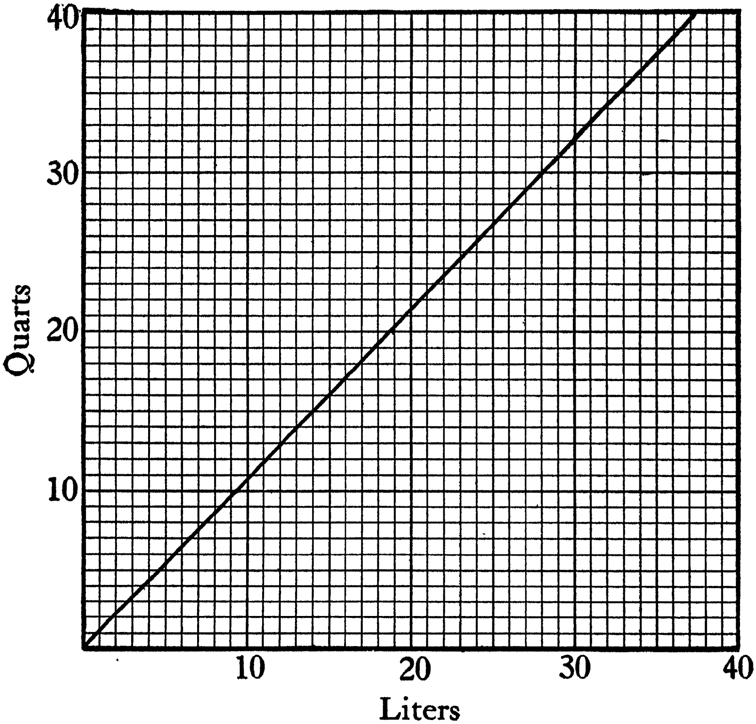
30. Using the graph for changing pounds to kilograms, complete the following table. *(Copy the table. Do not write in this book.)*

Pounds	*Kilograms*
10	5
6.5	
	27.5
80	
50	
	35
	17.5

31. Make a double bar graph to represent the most reliable and least reliable air-mail operations in 1935–1938. (Reliability here means per cent of miles scheduled in air-mail operations that were actually flown.)

Year	*Reliability*
1938	99.47
1938	77.67
1937	99.45
1937	85.24
1936	99.56
1936	80.30
1935	99.57
1935	76.94


100
80
60
40
20
Pounds
20
40
Kilos



32. Using the graph for changing quarts to liters, complete the following table. *(Copy the table. Do not write in this book.)*

Quarts	*Liters*
30	
	17
23.6	
	18.5
40	

33. The table below shows the per cent of flights completed. Construct a bar graph from this information.

Year	*Per cent*
1935	91.49
1936	95.60
1937	95.41
1938	95.37
1939	95.30
1940	96.02

34. The rate of production of planes in the month of September 1918 by countries was as follows:

Italy	374
United States	1,207
France	2,238
England	2,726

Use the data to construct a bar graph.

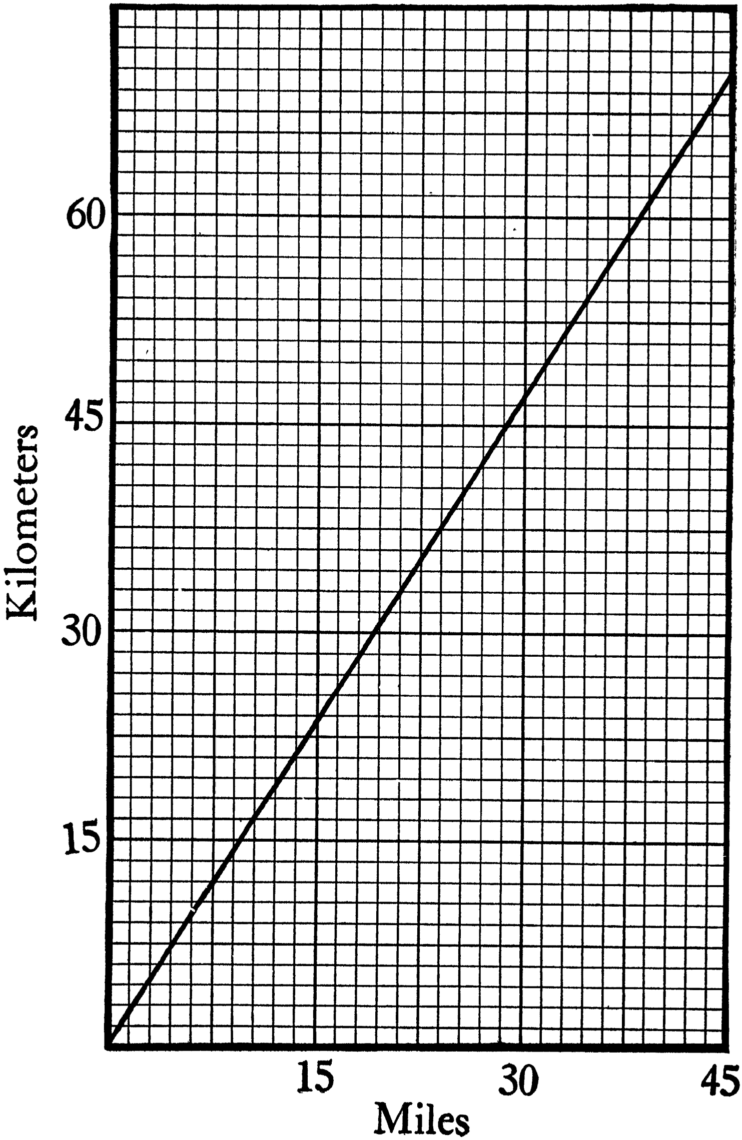
35. The heat distribution in the average aircraft engine is as follows:

	Per cent
Heat efficiency	25
Loss through exhaust	40
Loss through friction	4
Loss through conduction and radiation	4
Loss through cylinder cooling	27

Using the data given here, construct a circle graph.

36. Speed flights 1903–1934. Using the table given here, make a bar graph of the speeds attained in these record-breaking flights.

Year	*Country*	*m.p.h.*
1903	United States	30
1909	United States	47
1910	France	66
1912	France	106
1913	France	126
1919	United States	162
1920	France	194
1921	France	205
1922	United States	222
1923	United States	266
1924	France	278
1927	Italy	297
1928	Italy	318
1929	England	357
1931	England	406
1933	Italy	423
1934	Italy	440


Kilometers
60
45
30
15
15
30
45
Miles

37. The following table shows the amount of money appropriated each year from 1936 through 1942 for naval aviation. Construct a graph making use of these data.

Year	*Appropriation for Naval Aviation*
1936	$ 40,732,310
1937	38,588,270
1938	49,500,000
1939	48,075,000
1940	111,459,000
1941	452,319,950
1942	1,006,596,600

38. Using the graph for changing miles to kilometers, complete the following table. *(Copy the table. Do not write in this book.)*

Miles	*Kilometers*
10	
	7
25	
	40
6.5	
	33.2
27.25	
8.7	
	19.4
	17
60	

39. Make a bar graph showing the growth of aviation mileage in foreign extensions of United States airways.

Year	*Miles*	*Year*	*Miles*
1926	152	1932	19,980
1927	257	1933	19,875
1928	1,077	1934	22,717
1929	11,456	1935	32,184
1930	19,662	1936	32,658
1931	19,949	1937	32,572

40. Make a graph showing the number of ground employees per plane in the air. Use the following data.

1927	4
1930	5
1935	16
1941	48

41. The modern airplane is built so that it can fly $1\frac{3}{4}$ million mi. At a ground speed of 150 m.p.h., how many hours would a plane fly in order to complete its useful mileage?

42. Make a bar graph showing the average fare per mile, using this information.

	Cents
January 1929	12
January 1930	$8\frac{1}{2}$
January 1932	6
January 1942	5

43. Construct a graph showing the changes in United States and German operation between 1939 and 1941.

German Airways	*Miles* 1939*	*Miles* 1941*	*U.S. Airways*	*Miles† 1939*	*Miles† 1941*
Bolivia	4,109	0	Bolivia	795	4,904
Colombia	5,494	0	Colombia	1,274	6,769
Ecuador	1,210	0	Ecuador	363	953
Chile	0	0	Peru	1,256	1,256
Chile-Argentine	870	870	Chile	1,176	1,176
			Chile-Argentine	870	870

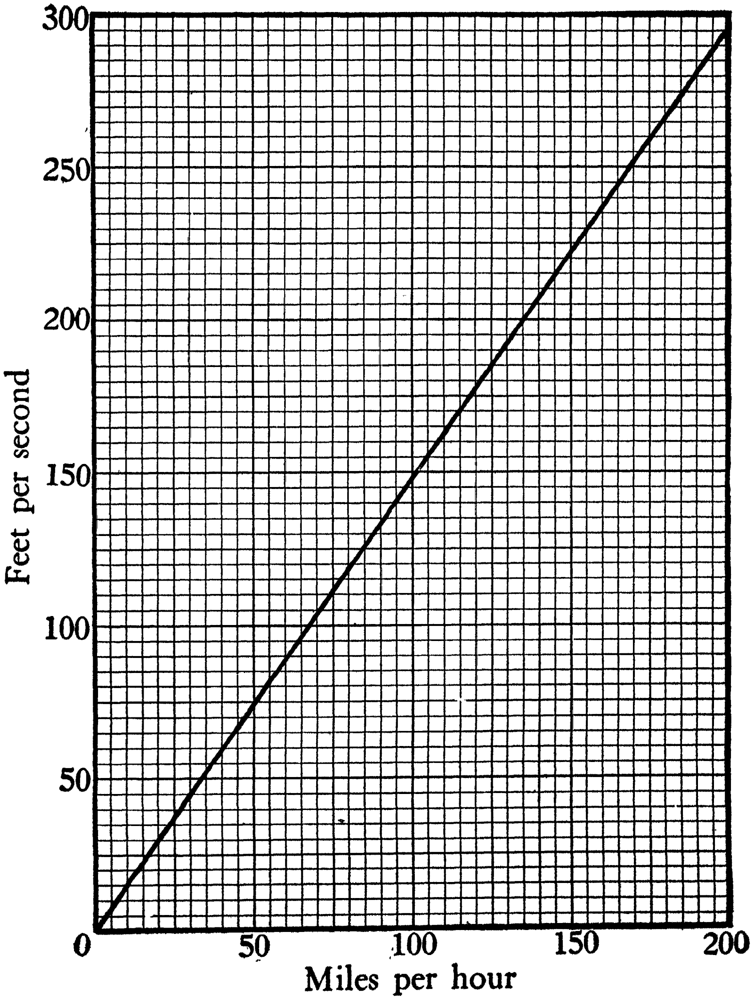
* Controlled or influenced.
† Operated or sponsored.

44. Following are the numbers of airplanes exported between 1935 and 1940. Represent the data graphically.

Year	*Planes Exported*
1935	334
1936	515
1937	621
1938	875
1939	1219
1940	3162

45. Export of airplane engines from 1935 to 1940 was as follows. Represent this information by a bar graph.

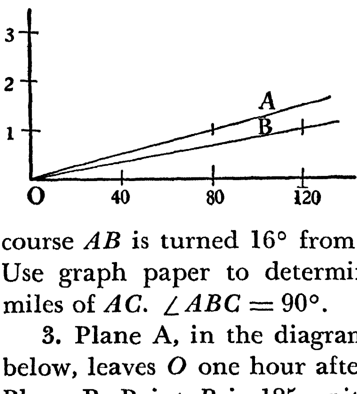
Year	*Engines Exported*
1935	568
1936	945
1937	1047
1938	1307
1939	1880
1940	4986



46. Using the graph on page 69 for converting miles per hour to feet per second, complete the following table. *(Do not write in this book.)*

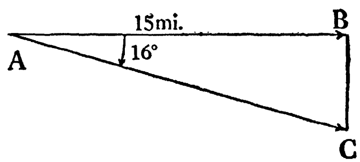
Miles per Hour	*Feet per Second*
75	
	80
150	
	250
	200

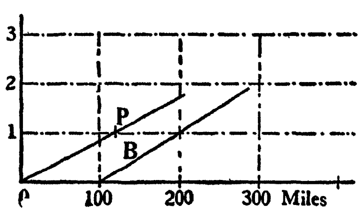
1. The horizontal axis represents miles. Hours are shown on the vertical axis. Make a diagram similar to this. Lines *A* and *B* represent rates in miles per hour of two planes. From your graph read the distance covered in 2 hr. 20 min. by Plane A, in 4 hr. 45 min. by Plane B.



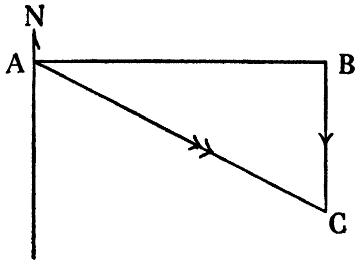
2. A carrier supporting a task force setting out on the course *AB* is turned 16° from the course by wind and current. Use graph paper to determine the approximate distance in miles of *AC*. $\angle ABC = 90°$.

3. Plane A, in the diagram below, leaves *O* one hour after Plane B. Point *P* is 125 units on the horizontal axis. Complete the diagram and determine the number of hours Plane A will fly before overtaking Plane B. How many miles will Plane A have flown?





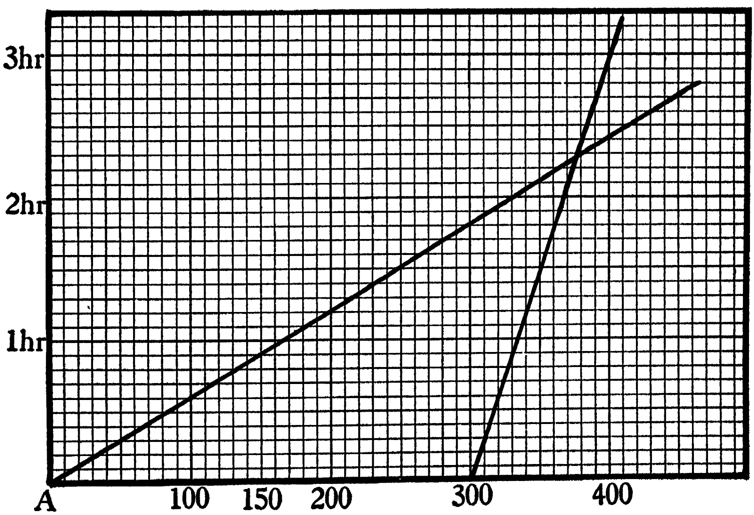
4. Drift is the angle between the course and the track made good. Use graph paper to determine the value of *AC* for the values of *AB* and *BC* given. Use a protractor, measure $\angle BAC$ in each of the following:



AB (air speed) m.p.h.	*BC (wind velocity)* m.p.h.
125	30
146	27
180	25

5. An airplane carrier steaming on a constant course at an average rate of 28 knots is followed after 10 hr. by a fighter plane traveling at a rate of 165 knots. How long will it take the plane to overtake the carrier? Show time on the vertical axis, distance on the horizontal axis.

6. An airplane which travels at an average speed of 175 m.p.h. sets out to overtake a steamer making an average speed of 10 m.p.h. after the steamer has been underway from the port of departure 30 hr. How long will it take the plane to overtake the steamer? Solve graphically as in the illustration.



7. If a ship has been sailing a constant course for 24 hr. at a rate of 20 knots, how long will it take a flying boat traveling at 115 knots, starting from the same port, to overtake it? Solve graphically.

8. A plane starts from Tallahassee and flies eastward. At the same time a plane leaves New Orleans, which is 349 mi. west of Tallahassee, and flies in the same direction as the first plane. If the first plane's ground speed is 112 m.p.h., at what rate will the second plane need to fly in order to overtake the first one in 5 hr.? (No wind.) Solve graphically.

9. If a military plane flies at the rate of 175 m.p.h., how long will it take a pursuit plane flying at 220 m.p.h. to overtake the first plane if the slower plane has a start of 1 hr. 45 min.?

10. If the time required to cover a 10-mi. track section is 3 min. 48 sec., how long will it take to complete the journey to your destination 165 mi. along the track? Solve graphically.

11. A plane flying at an average speed of 160 m.p.h. starts out to overtake a carrier that left port 4 hr. earlier. The carrier is steaming at an average rate of 26 m.p.h. How long will it take the plane to intercept the carrier? Solve graphically.

12. The cost of 7 gal. of gasoline and 2 qt. of oil is $2.66. The bill for 9 gal. of gasoline and 5 qt. of oil was $4.27. Find the cost per gallon of gasoline and per quart of oil.

CHAPTER 9

AIRPLANES

1. The best ground time between cities is given in the first column, the air-line time in the second column. Find the amount of time saved in each case by going by plane.

Between	*Best Ground Time*	*Air-line Time*
New Orleans and Chicago	20 hr.	6 hr. 20 min.
St. Louis and Chicago	4 hr. 55 min.	1 hr. 40 min.
Jackson and St. Louis	14 hr. 53 min.	3 hr. 10 min.
Shreveport and Houston	7 hr. 15 min.	1 hr. 25 min.

2. Combustion in a gasoline engine takes place as a wave of flame traveling from the spark plug at about 100 ft. per second. Change this rate to miles per hour.

3. Airplane engines cost from $15 to $20 per rated horsepower. If the cost per rated horsepower of a certain engine is $17, what is the cost of the engine if the rated horsepower is 450?

4. In May 1941 the Germans dropped bombs from about 500 planes in one raid. If the average bomb load is 2,000 k., what was the total weight of bombs dropped?

5. In 1940 the Piper Aircraft Corporation delivered 3,016 Piper Cubs. At $995 each what was the value of the planes delivered?

6. After 600 hr. of flying time transport planes are sent to the shop for complete overhaul. Assuming an average ground speed of 150 m.p.h., how far, on the average, do these planes fly before being overhauled?

7. In March 1942 a bomber was flown from Newfoundland to England, a distance of 2,200 mi., in 6 hr. 40 min. What was the rate of speed of the bomber in miles per hour?

8. About 35,000 rivets go into a typical pursuit plane. In

the construction of a bomber 150,000 rivets are used. At $0.05 per rivet, what is the cost of riveting on a pursuit plane? a bomber?

9. A P-38 Lockheed interceptor pursuit plane can climb a mile in the first minute. If the rate of climb remains the same, how many feet can it climb in 90 sec.? in 2 min.?

10. The horsepower hour is the number obtained by multiplying the horsepower by the number of hours the engine is running.

From the following data find the number of horsepower hours in each case.

H.P.	*Hr.*
235	4
1,100	6
725	7
842	3

11. British engines sell for $15 to $20 per horsepower plus 30% for duty and freight. What would be the average cost in the United States of British engines of horsepower ratings of 300, 700, and 850?

12. Airplane engines in the United States cost about $10 per horsepower. Find the approximate cost of engines having the following horsepower ratings: 250, 450, 1,500.

13. The Boeing Clippers have a fuel capacity of 5,400 gal. If the tanks are full at the start of a flight, what is the weight of gasoline in the tanks? If the clipper uses 850 gal. of gasoline in the first zone of the trip, what reduction in weight does this represent?

14. It requires 185 men operating in three 8-hour shifts to carry out the necessary mechanical overhaul of the *Atlantic Clipper* after each crossing. How many man-hours of work is this? (Consider all 185 men operating in 1 shift.)

15. The CW-20 has a speed of $3\frac{1}{2}$ mi. per minute. How many miles per hour is this? How far can it travel in 3 hr.? in 5 hr.?

16. In the Buick factory 5,000 engines of a type developing 1,200 horsepower are to be built. What is the total horsepower represented by this number of engines?

17. A V-type 12-cylinder Liberty engine developed 422 H.P. It weighed 2 lb. per horsepower. What was its weight?

18. A Ford trimotor transport plane of 1929 had a gross weight of 13,500 lb. Its engines developed 1,260 H.P. What was the horsepower per pound of gross weight?

19. A transport plane of 1942 has a gross weight of 25,000 lb. and develops 2,400 H.P. What is its horsepower per pound of gross weight?

20. A clipper returns from Lisbon to New York. Two days before its departure a staff of 185 mechanics operating through three 8-hour shifts performed work on and checked some 1,500 separate items required by maintenance routine. (This service originally took 6 da.) If a clipper makes 20 trips a year from New York, how many days are saved yearly by the faster check-up methods?

21. At the rate of $1.00 per air-hour per $1,000 invested, how many air-hours are required to write off the cost of a transport plane that cost $215,000? At 145 m.p.h., how many miles will that be?

22. A bomber was flown from Newfoundland to England in March 1942, approximately 2,200 mi., in 6 hr. 40 min. If the plane was expected to have a top cruising speed of 275 m.p.h. what was the rate of the wind that was helping the plane?

23. A thickness gage has 6 tempered-steel leaves of the following thicknesses:

a. 0.0015	*d.* 0.0020
b. 0.0030	*e.* 0.0040
c. 0.0060	*f.* 0.0015

Which 4 leaves add up to 15 thousandths? What is the sum of all 6 leaves?

24. A plane flying from New York to Chicago, an airway distance of 725 mi., arrives at a point 480 mi. from New York in 3 hr. The plane requires 2 hr. for the trip from this point to Chicago. What is the rate of the plane for the last 2 hr. of the trip?

25. The Gulf Coast Air Corps Training Center had 6,992 aviation students in training on December 1, 1941. This was 18 times its training strength in February 1941. How many were in training in February 1941?

26. An automatic radio receiver can copy 17,500 words in 2 hr. How many words is that per second?

27. If the cruising speed of a plane is 170 m.p.h., how long will it take the plane to go 650 mi. if there is no wind? How long will it take against a wind of 25 m.p.h.? with a wind of 25 m.p.h.?

28. The direct labor man-hours required for building a heavy bomber is 80,000 hr. How many days, on the average of 8 hr. each day, would be required for 200 men to build a bomber?

29. If the cruising speed of a plane is 120 m.p.h., how long does it take the plane to go 800 mi. with no wind blowing? How long does it take with a head wind of 20 m.p.h.? how long with a tail wind of 20 m.p.h.?

30. Some bombers are equipped with bomb racks that allow selection of different weight bombs. If a bomber has a bomb capacity of 1 ton, how many 30-lb. bombs can it carry? how many 50-lb. bombs? how many 150-lb. bombs?

31. If a typical transport plane of 1928 cost $23,000, and this was at the rate of $12 per pound of useful load, how much useful load could such a plane carry? The cost of a 1940 transport plane is $120,000. This is at a cost of $22 per pound of useful load. What is the useful load of this plane?

32. Foodstuffs and galley supplies on a clipper weigh 256 lb. How many pounds each is this for 30 passengers and a crew of 8?

33. The cruising speed of a plane is 135 m.p.h. How long will it take to fly 3,250 mi.? (Express your answer to the nearest minute.)

34. At what speed should a plane fly in order to travel 582 mi. in 3 hr.?

35. The distance from San Francisco is 2,400 mi. How long would it take a Boeing Flying Fortress to reach Pearl Harbor if its cruising speed is 215 m.p.h.? (Express the result to the nearest hour.)

36. A large flying boat is powered by 2 motors of 9 cylinders each. If the engines develop a total horsepower of 2,400, what is the average horsepower represented by each cylinder?

37. A pilot travels a distance of 520 mi. between 10:00 A.M. and 2:30 P.M. What is his average speed? At this speed how far would he fly in 12 hr.?

38. A plane going from *A* to *B*, a distance of 450 mi., makes

the trip in 2 hr. The plane is helped by a tail wind of 50 m.p.h. What is the rate of the plane when the wind is not blowing?

39. The total air service of the United States early in 1917 was 1,300 officers and men. At the time of the Armistice there were approximately 20,000 officers and 179,000 men in the air service. How many times as many men were in this service at the end as were in it at the beginning of the war?

40. The U.S.S. *Saratoga* is rated at 180,000 H.P. Eight motors are used to propel the ship. What is the horsepower of each motor?

41. The U.S.S. *Hornet* was completed at a cost of $32,000,000. This carrier has a displacement of 19,900 tons. What was the cost per ton?

42. If the cruising range of a Piper Coupé is 455 mi. and the plane has a capacity of 25 gal. of fuel, how many miles can it travel on a gallon of gasoline? The cruising speed of this plane is 96 m.p.h. How much gas does it use in 1 hr.?

43. Aircraft are classified according to gross weight as follows:

Class	*Gross Weight*
1	not more than 1,500 lb.
2S	1,500 lb.– 4,000 lb. (single-engine)
2M	1,500 lb.– 4,000 lb. (multi-engine)
3S	4,000 lb.–10,000 lb. (single-engine)
3M	4,000 lb.–10,000 lb. (multi-engine)
4S	10,000 lb.–25,000 lb. (single-engine)
4M	10,000 lb.–25,000 lb. (multi-engine)
5	in excess of 25,000 lb.

a. What is the difference in weight between the lower limit of Class 2S and the upper limit of Class 3M?

b. In which class does an airplane of 5,750 lb. gross weight fall if it has 2 engines? How many pounds more than the lower limit is this weight?

c. A 4-motor plane weighs 16,250 lb. In what class is it?

d. In which class does a plane come whose gross weight is 1,750 lb. if it has 1 engine?

e. In which class does a plane come whose gross weight is 1,850 lb. if it has 2 engines?

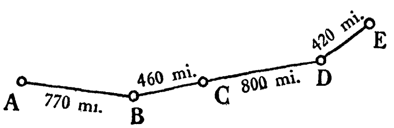
f. In each case what is the difference between the weight of the plane and the lower weight limit of the next higher class?

g. In which class does a plane come if its gross weight is 26,500 lb.? How many pounds more than the lower limit of this class is the weight of the plane?

44. A plane whose direction of flight is with the wind, and the wind velocity is 40 m.p.h., travels 450 mi. in 3 hr. What is the rate of the plane in still air?

45. The paymaster in charge of commissary supplies on a carrier estimates that he will need to provide coffee twice daily to a crew of 1,500 men. The coffee is to be made in two 80-gal. urns and three 20-gal. urns. He figures on 20 lb. of coffee for each 80-gal. urn and 5 lb. for each 20-gal. urn. How many 100-lb. drums of coffee should be requisitioned for 30 da.?

46. A plane can "dust" 300 acres of cotton per hour. An average of 3 lb. of chemicals are used per acre. If the plane operates 5 hr. on 1 trip, how many acres will it dust and how much insecticide will it use?

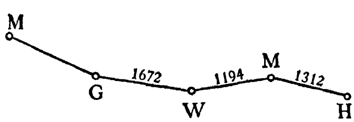


47. At a cruising speed of 185 m.p.h., how long will it take a bomber to fly over the route in the map?

48. Two airplane hulls are the same in form. The weight of the one made of wood is 2,340 lb. The weight of the metal hull is 1,825 lb. How much weight has been saved by metal construction? What per cent is this of the weight of the wooden hull?

49. The cruising speed of one of the Navy blimps is 65 m.p.h. Operating at its regular cruising speed, how many miles will it travel between 8:00 A.M. and 4:00 P.M. while patrolling the coast?

50. The distance from Honolulu to Manila by the route shown in the sketch is 5,771 mi. By making use of the distances given, find the number of miles from Guam to Manila.



51. Time in R.A.F. reports and calculations is measured as so many hours and minutes from 0 time, which is taken as midnight. For example, 2:00 P.M. is 1400 hr.; 3:45 P.M. is 1545

hr. Express in the same manner: 2:15 A.M., 6:30 P.M., 8:50 P.M., 9:15 P.M., 11:45 P.M.

52. The U.S.S. *Hornet,* an airplane carrier, was commissioned in October 1941. The keel of this ship was laid in September 1939. How many months were required for the completion of this carrier?

53. The empty weight of a Model 90 AF is 998 lb. Its useful load is 640 lb. What is its gross weight?

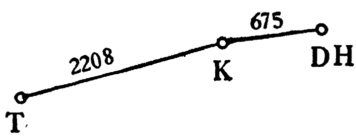
54. The maximum speed of the Franklin 90 AF is 130 m.p.h. Its landing speed is 45 m.p.h. How much greater is the maximum speed than the landing speed? If the cruising speed is 115 m.p.h., how long will a flight of 785 mi. take at the cruising speed?

55. The Curtiss-Wright CW-20 can carry 36 passengers by day or 20 by night (in berths). It has been adopted by the army as a long-range troop carrier. Find the weight of 36 soldiers averaging 155 lb. in weight plus their equipment, averaging 65 lb. per man, carried on a flight of the CW-20.

56. Find the difference between the top speeds and the cruising speeds of the planes whose speeds are given blow.

High Speed	*Cruising Speed*
140	125
199	179
226	210
150	130
314	282
235	176
323	262

57. A plane traveled approximately by straight-line routes from point to point as shown in the diagram. If the total flying time was 12 hr., what was the average speed for the trip?



58. A plane travels 1,750 mi. between 1:00 P.M. and 8:30 P.M. What is the average speed for this distance?

59. At 6:30 A.M. a plane sets out from Floyd Bennett Field and lands at an airport at 3:45 P.M. If the distance flown is 1,100 mi., what was the plane's average speed?

60. Before it is weighed, the flying boat must be placed in what is called 0° longitudinal trim angle and 0° heel angle. The weights on the two forward jacks were 15,500 lb. and 15,430 lb., and those on the rear jacks 10,400 and 10,240 lb. Find the weight of the clipper. If each weighing machine is accurate to $\frac{1}{2}$ of 1%, what is the weight tolerance for each jack load? for the total load?

CHAPTER 10

AVERAGE

1. The one-way fare between Chicago and Pittsburgh is $23.95. The air distance between Chicago and Pittsburgh is 359 mi. Find the average fare per mile.

2. The weights in pounds of first-class mail on 10 trips between two cities were as follows: 750, 546, 748½, 654, 327, 548, 672, 378, 442, 756. What was the average load of first-class mail carried by this mail plane?

3. A plane flies 850 mi. in 5 hr. 24 min., using 72 gal. of fuel. What was the average speed in miles per hour and the fuel consumption in miles per gallon?

4. In measuring the diameter of a wire with a micrometer screw gage, the following estimates are made: 2.24 mm., 2.25 mm., 2.22 mm., 2.26 mm., 2.27 mm. Find the average reading.

5. The *Caribbean Flyer* leaves New York at 6:00 A.M. and arrives in Miami at 9:15 P.M. The air distance is 1,233 mi. Find the average speed in miles per hour.

6. The amount of time required for flying between *A* and *B* for 10 trips is given below. What is the average amount of time required?

10 hr. 30 min.	8 hr. 50 min.
9 " 40 "	8 " 30 "
10 "	9 " 20 "
7 " 50 "	9 " 45 "
9 " 20 "	8 " 25 "

7. The specific fuel consumption (pounds per horsepower hour) is given for 10 planes. Find the average specific fuel consumption.

0.53	0.582
0.51	0.475
0.495	0.482
0.486	0.491
0.551	0.472

8. The gross weights of 10 planes are as follows:

5,628	4,001
4,200	4,001
3,800	3,250
3,250	2,650
4,200	3,950

Find the average gross weights.

9. The aviation gasoline tax in 12 states is given below. What is the average tax to the nearest mill?

	Per Gallon		*Per Gallon*
Alabama	$0.06	Delaware	$0.04
Arizona	.05	Florida	.07
Arkansas	.065	Maryland	.04
California	.03	Missouri	.02
Colorado	.04	Ohio	.04
Connecticut	.03	Oregon	.05

10. Below are given the weights of the 5 men in the crew of each of 3 Navy transport planes. Which of the 3 planes has the lightest crew? What is the average weight per man for each crew? average weight per man for the 3 crews?

A	*B*	*C*
147	182	146
175	138	178
168	169	164
152	141	129
140	137	152

11. The ideal weight for parachutists for the army is considered to be 145 lb., although men weighing as much as 185 lb. will be accepted for this service. Following are the weights of 10 men in the parachute service. What is the average weight? How close is this to the ideal weight?

186	163
174	140
138	171
127	160
154	147

12. The high speed of each of 7 planes is given here. What is the average high speed?

201	200
163	270
261	261
250	

13. The one-way air-line fare between Chicago and New York is $44.95. What is the average fare per mile if the air distance is 725 mi.?

14. The *First Sky Chief* leaves New York at 5:15 P.M. E.W.T. and arrives in Chicago at 9:15 P.M. C.W.T. The air distance between the cities is 725 mi. What is the average ground speed in miles per hour?

15. In August 1940 the United Air Lines began scheduling 2,270,000 miles of flying per month, increasing schedules on both the Eastern and Pacific Coast divisions of the system to meet increased travel. The United Air Lines used 48 planes for these services. What is the average monthly mileage per plane?

16. The fuel consumption of a plane on 10 different trips over the same route was:

Gallons	*Gallons*
120	135
117	128
146	170
140	132
160	138

What was the average number of gallons used per trip?

17. Aspect ratios of 8 planes of the same general type are:

9	8
$7\frac{1}{2}$	$6\frac{1}{2}$
6	$8\frac{1}{2}$
$7\frac{3}{4}$	$6\frac{1}{8}$

What is the average aspect ratio?

18. The wing areas of 7 single-engined planes are given below. A designer wishes to plan the construction of a plane that will be similar to these but better in most respects. One of the things he does is to compare the wing areas. What is the average of those given?

Square Feet
174
174
200
200
240.4
116.7
123

19. The high speeds of 7 modern planes are as follows:

Miles per Hour
199
226
140
150
210
314
323

Find the average speed of the planes.

20. The *Sky Hawk* leaves New York at 10:45 A.M. and arrives in Pittsburgh at 1:08 P.M. The air distances between the cities is 359 mi. Find the average ground speed in miles per hour.

21. A plane is scheduled to leave Toronto at 11:15 P.M. (E.S.T.) and arrive in Halifax at 6:15 A.M. (A.S.T.). The air distance between Toronto and Halifax is 885 mi. What is the average rate in miles per hour?

22. The *Sky Century* leaves New York at 9:35 A.M. and arrives in Pittsburgh at 1:05 P.M. What is the average speed in miles per hour for the trip if the distance between the cities is 359 mi.?

23. The *Second Sky Chief* leaves Los Angeles at 8:00 P.M.

and arrives in Albuquerque at 12:52 A.M. The air distance between the two cities is 710 mi. Find the average ground speed in miles per hour.

24. A plane flying from A to D by way of B and C took the following lengths of time for the distances given. What was the average speed per hour for the entire trip?

	Miles	*Time*
A to B	700	4 hr.
B to C	300	2 hr.
C to D	200	1 hr. 30 min.

25. A plane left Las Vegas for Los Angeles, a distance of 427 mi., and arrived in 2 hr. 45 min. On its return it required 3 hr. What was the average ground speed for the round trip?

26. The air distance from Montreal to Boston is 263 mi. If a plane flies to Boston from Montreal in 2 hr. and makes the return trip in 2 hr. 30 min., what is the average speed in miles per hour for the entire trip? What is the average speed going? the average speed returning?

27. An airplane flies 850 mi. in 5 hr. 45 min., using 80 gal. of fuel. How many miles per gallon of gasoline did the plane travel?

28. The airway distance between Philadelphia and Cleveland is 404 mi. A plane takes 2 hr. 30 min. to fly one way and 1 hr. 50 min. for the return flight. Find the average ground speed.

29. A plane leaves Los Angeles at 10:00 A.M. and arrives at Oakland at 12:15 A.M. On its return it leaves Oakland at 4:15 P.M. and arrives at Los Angeles at 6:45 P.M. The airway distance between the cities is 327 mi. What is the average ground speed for the round trip?

30. A plane flies from San Diego to Los Angeles, an airway distance of 123 mi., in 50 min. The return trip requires 1 hr. 12 min. What is the average ground speed for the round trip?

31. The airway distance from New York to Cleveland is 418 mi. A plane leaves Cleveland at 7:00 A.M. and arrives in New York at 9:30 A.M. Returning, it leaves New York at 12:15 P.M. and arrives in Cleveland at 4:30 P.M. What is the average ground speed for the entire trip?

32. A plane flew from Tampico to Guatemala, a distance of 882 mi., in 5 hr. and made the return trip in 6 hr. If the aver-

age air speed was the same going and returning, what was the average air speed and the average rate of the wind? What was the average ground speed for the round trip?

33. On February 27, 1942, Pan American Airways completed its 500th Atlantic crossing since May 1939. During this time the number of passengers carried was 14,135. Find the average number of passengers per crossing. On these 500 trips the plane flew a total of 2,175,006 mi. What was the average number of miles per crossing? During this time the clippers carried 1,272,000 lb. of mail. Find the average weight of mail carried per crossing.

34. Some years ago the Dornier Do-18 flying boat flew from the catapult-ship *Westfalen* near Plymouth to Brazil (a distance of 8,400 kil.) in 43 flying hours. What was the average speed in miles per hour?

35. The *Cambria,* of the Imperial Airways, flew from Botwood in Newfoundland to Foynes in Eire in $10\frac{1}{2}$ hr. The air distance is 1,993 mi. What was the average ground rate in miles per hour?

36. A plane uses 76 gal. of gas to fly 800 mi. The flight time is 5 hr. 30 min. Find the average speed in miles per hour and the average number of miles flown per gallon.

37. The scheduled daily mileage for 6 round trips between Washington and Detroit is 4,824. Find the average length of a one-way trip.

38. Find the average weight of aircraft engines having weights as follows: 231.11 lb., 322.11 lb., 322.76 lb., 324.76 lb., 329.76 lb.

39. Find the average bore of the engines having the following bores: $4\frac{1}{4}$ in., $4\frac{5}{8}$ in., 5 in., $4\frac{1}{8}$ in., 4.375 in.

40. The stroke for each of 5 engines is: $5\frac{1}{4}$ in., $5\frac{1}{4}$ in., $5\frac{1}{2}$ in., 4 in., 3.875 in. Find the average stroke.

41. Find the average horsepower of 5 engines having the following horsepower ratings: 285, 330, 350, 450, 450.

CHAPTER 11

METRIC SYSTEM

1. If a kilogram is approximately 2.2 lb., how many pounds will a bomb load of 175 kilos weigh? one of 2,000 kilos? one of 1,850 kilos?

2. To change ounces to grams multiply by 28.35. Find the weight in grams of the following model airplane parts weighing the following numbers of ounces: 6, 8, 5.5, 4.3, 2.8.

3. To find the number of liters multiply gallons by 3.785. The fuel capacity of the clipper is 5,400 gal. How many liters is this?

Complete the following table. *(Do not write in this book.)*

Gallons	*Liters*
200	
	175
	2560
	560
380	
400	

4. When passage is purchased in Colombia for children's passage on *Avianca* the following special rates apply: Under 15 yr. of age and weighing less than 25 kilos, one-third normal adult fare; under 15 yr. and weighing 25 kilos and not more than 50 kilos, two-thirds normal adult fare.

John is 14 and weighs 95 lb. At what rate will his fare be figured? Helen is 13 and weighs 75 lb. What part of the regular adult fare is required for her? Jean is 9 and weighs 53 lb. What part of one adult fare is required for her?

5. On Latin-American services when one-way fare is $400 or less in United States currency, 25 kilos of baggage are carried free; $401.00 United States currency (or more), 30 kilos; $501.00 United States currency (or more), 35 kilos; 7 kilos for those

traveling at $\frac{1}{3}$ fare; and 14 kilos for those traveling at $\frac{2}{3}$ fare. What is the minimum baggage allowance in kilos for John, Helen, and Jean in problem 4?

6. The baggage allowance on the Atlantic, Pacific, and Alaska services is 7 kilos irrespective of the fare paid. If there are 12 passengers on a plane going from Seattle to Fairbanks and the total weight of their baggage is 240 lb., how much in excess of the baggage allowance is this? What is the average excess per passenger? (Express the answers in kilograms.)

7. George is 14 and weighs 112 lb. What part of the adult fare is required for him for travel on *Avianca?* What is his minimum baggage allowance? Express this in pounds.

8. The galley equipment and general supplies of the clipper consist of the following items. Find the total weight.

Ice	50	lb.
General galley equipment	127	kilos
Icebox	$9\frac{1}{2}$	kilos
Cup racks	1.5	kilos
Sink	2	kilos
2 quarts of water for steam table.		

9. The fares in Mexican currency between the following points are as follows:

	Pesos
Chihuahua—Ciudad	58.14
Mexico City—Durango	163.36
Monterrey—Torreon	54.86

The exchange rate is calculated at 5 to 1. What is the United States currency value of each fare quoted? Find the equivalents in Mexican currency of the following fares given in United States currency: \$9.71, \$15.65, \$42.38.

10. Foreign business travelers in Venezuela must deposit the sum of 500 bolivars, Venezuelan currency, with the carrier on which they enter Venezuela. If a bolivar is worth approximately \$0.32 of United States currency, what is the amount of this deposit in dollars?

11. The milreis has an average value of \$0.05. The hotel bill for dinner for passengers and crew at a hotel was 972 milreis. How much is that in United States currency?

12. The port steward in Rio signed vouchers totaling 24,368 milreis in connection with one call of the clipper. How much United States money does this represent?

13. Because of varying baggage allowances due to differences in fares, the baggage allowances for passengers on a certain flight were as follows: 3 were allowed 25 kilos each, 7 were allowed 30 kilos each, 8 were allowed 35 kilos each. The baggage carried amounted to 1175.3 lb. Was this in excess of the allowance; if so, what was the excess?

14. The escudo has an average value of $0.04. If the bill for dinner for 30 passengers and 12 crew members on the *Atlantic Clipper* was 1,562 escudos at a restaurant in Lisbon, what was the cost of this meal in dollars? per person?

15. Because of weather conditions a transatlantic flight was delayed, and passengers and crew were accommodated at a hotel. The bill for supper, lodging, and breakfast was 12,600 escudos. How much was this per person?

CHAPTER 12

RATIO

ASPECT ratio may be found from this formula:

$$A = \frac{\text{span}^2}{\text{area}}$$

1. Find the aspect ratio from the data given here. *(Do not write in this book.)*

Area square feet	*Span feet*
340	35
500	100
250	32
400	92

2. In August 1940 the United Air Lines employed 2,969 people. Of these, 400 were pilots and 200 stewardesses. How many employees on the ground were there for each one working in the air?

3. A plane flying 130 m.p.h. goes a certain distance in 2 hr. 30 min. How long would it take to cover the same distance flying 120 m.p.h.?

4. If a plane flying 140 m.p.h. covers a certain distance in 3 hr. 45 min., how long would it take to cover the same distance flying 150 m.p.h.?

5. If a plane flying 125 m.p.h. covers a given distance in 7 hr., how long will it take to cover the same distance flying at 140 m.p.h.?

6. The useful load of the Boeing Clipper is about 32,000 lb. A railroad box car has a capacity of 40 tons. What is the ratio of the box-car load to the useful load of the plane?

7. At an engine speed of 1,200 r.p.m., what is the propeller speed if the ratio of engine speed to propeller speed is 16/9?

8. A plane flying at the rate of 110 m.p.h. covers a certain distance in 2 hr. 24 min. How long would it take a plane flying at 125 m.p.h. to cover the same distance?

9. If the time required to cover a 10-mi. track section is 3 min. 18 sec., how long will it take to go 190 mi. beyond the end of the section?

10. A typical emergency meal used by Pan American Airways for 30 people consists of the following items:

2 46-oz. cans tomato soup	2 tins cherries
14 tins hamburgers	1 tin evaporated milk
6 #2½ cans string beans	100 individual packages of sugar
1 gal. shoestring potatoes	3 packages of Melba toast

Estimate the size of each item for a meal for 45 people.

11. An airplane flying at 140 m.p.h. covers a distance in 3 hr. 15 min. At what rate would the plane need to fly in order to cover the same distance in 2 hr. 30 min.?

12. A plane flying at 160 m.p.h. covers a certain distance in $2\frac{3}{4}$ hr. At what rate would it need to fly in order to cover the same distance in 3 hr.?

FORMULA

$$\text{speed range of plane} = \frac{\text{high speed}}{\text{landing speed}}$$

$$\frac{140\ m.p.h.}{40\ m.p.h.} = 3.5\ \text{(speed range)}$$

13. Knowledge of the ratio of maximum high speed to minimum landing speed is important to designers. Find this ratio for each of the following planes:

Plane	*Maximum High Speed m.p.h.*	*Minimum Landing Speed m.p.h.*
A	210	68.5
B	125	47
C	75	31
D	185	64.5

14. A carrier traveling at 24 knots covers a certain course in 15 hr. 30 min. How long will it take the carrier steaming at 28 knots to cover the same distance?

15. If the gear ratio between engine and propeller of the clippers is 16/9, and the engine makes 2,400 r.p m. in starting, what is the number of propeller revolutions per minute?

16. If a rectangular wing has an area of 280 sq. ft. and an aspect ratio of $7\frac{1}{2}$, what is the chord length of the wing?

Factor of safety is the term used to indicate how closely we may approach the *designed* load factor without damaging the airplane. This is expressed as parts of the designed load factor.

If a plane has a designed load factor of 12 and we can impose a load of 6 through the use of the controls, the airplane is said to have a factor of safety of 2.

17. If a plane has a designed load factor of 15 and we can impose a load of 10, what is the factor of safety?

18. From the data in the following table find the factor of safety in each of the following:

Designed Load Factor	*Imposed Load*
17	10
12	8
14	$7\frac{1}{2}$
15	9

19. The horsepower to drive an airplane is proportional to the cube of the velocity. If 220 horsepower is required to fly a plane 130 m.p.h., how many horsepower would be required to fly it at 140 m.p.h.?

20. Find the aspect ratio in each of the following:

Span feet	*Chord feet*
3	$\frac{1}{2}$
17	$2\frac{1}{2}$
30	5
42	6

21. If a wing span is 146 ft and the aspect ratio is $7\frac{1}{2}$, what is the length of the chord?

22. Given a wing span of 152 ft. and a chord of 19, what is the aspect ratio?

23. A plane starts from Washington to Buffalo at the same time that one leaves Buffalo for Washington. The air distance between the cities is 329 mi. After 1 hr. of flight the planes

pass at a point 160 mi. from Washington. How long did the plane require for the trip from Buffalo to Washington?

24. A 5-in. anti-aircraft gun is a gun having a bore diameter of 5 in. The term caliber is used to indicate the size of the bore. The term caliber also applies to the ratio of the length of the barrel to the bore of the gun. A 25-caliber gun is one in which the barrel is 25 times the bore. What is the length of a 25-caliber 5-in. gun? (It is usual to add 1 caliber to the answer obtained to the question above, as the breech mechanism is about 1 caliber in length.)

25. What is the total length of one of the 8-in. guns mounted in turrets on the U.S.S. *Saratoga* if the caliber of the gun is 45?

26. What is the total length of a 16-in. 45-caliber gun?

27. An airplane flying 130 m.p.h. covers a distance in 3 hr. 15 min. At what rate would it have to fly to cover the same distance in 2 hr. 25 min.?

CHAPTER 13

PERCENTAGE

1. A bolt may have a tolerance of 4%. A bolt expected to be 7 in. long is found to be $7\frac{1}{8}$ in. long. Is the error within the limit of tolerance?

2. A bolt made to be $3\frac{1}{2}$ in. in length may have a tolerance of $\frac{1}{32}$ in. What is the per cent of tolerance?

3. A bill of airplane supplies amounts to $1,650. The buyer is offered a choice of discounts. One is a straight 12%, and the other a 10% and 5%. Which is the better for the buyer?

4. A mixture of 40% alcohol, 35% gasoline, 17% benzol, and a small percentage of ether has been used successfully as airplane engine fuel. In 650 gal. of mixed fuel of this kind, how many gallons of alcohol are there? of benzol? of gasoline?

5. In 1935 the 68,372 passengers carried by Imperial Airways constituted 51% of the total European air traffic from Croydon. What was the total number of air passengers from Croydon?

6. In estimating how much gasoline should be used in a flight it is usual to allow a margin of 20% of the fuel capacity for safety. If a plane carried 175 gal. of gasoline, how much gasoline can be safely used on a flight?

7. Formula for volumetric efficiency of an airplane engine:

$$\frac{\text{volume of charge}}{\text{piston displacement}} = \text{volumetric efficiency in per cent}$$

Find the volumetric efficiency of an engine if the volume of charge is 778 cu. in. and the piston displacement is 897 cu. in.

8. The mean chord of an elliptical wing is located 41% of the distance from the root of the semi-span. Find the location of the mean chord when the semi-spans are: 38 ft., 27 ft., 40 ft., $28\frac{1}{2}$ ft.

9. Aluminum alloys are very similar to pure aluminum in appearance, but they are much harder and stronger. The following table shows the composition and various alloying metals used with aluminum.

	Aluminum	*Copper*	*Manganese*	*Magnesium*	*Silicon*
3s			1.25		
17s	92.0	4.0	0.50	0.5	
24s	92.0	4.2	0.50	1.0	
25s		4.5	0.80		0.8
51s				0.6	1.0

What is the weight of aluminum in a frame member which weighs 72 lb. if the alloy is 17s? What is the weight of copper in this same part?

10. The useful load of a plane is 1,085 lb. Its empty weight is 3,152 lb. Express the ratio of useful load to empty weight as a per cent.

11. The loading pumps are capable of fueling a plane at the rate of 100 gal. per minute. Usually, however, the rate is slower than this because of the use of such precautions as straining the fuel. How long will it take to pump 2,400 gal. of gas into the tanks of a clipper if the pumps are working at 72% capacity?

12. An analysis of pig iron shows that it is made up of 92% iron, 4% carbon, $1\frac{1}{2}$% silicon, $\frac{1}{2}$% each of sulphur, phosphorus, and manganese. In a carload of 40 tons how much manganese is there? how much silicon? how much iron?

13. If the air speed of a plane is 140 m.p.h., find the velocity of the winds that would be 15% of the plane's speed, 20% of the plane's speed, $22\frac{1}{2}$% of the plane's speed, 30% of the plane's speed.

14. The test pressure in pounds of hose for use in oil lines is 1,500. The safe working pressure is 800 lb. What per cent of the test pressure is the working pressure?

15. The bursting pressure in pounds of a type of hose used in vacuum lines is 1,600 lb. The working pressure is 700 lb. What per cent of the bursting pressure is the working pressure? If the test pressure of the hose is 1,200 lb., what per cent of the test pressure is the working pressure?

16. An analysis of a sample rivet used in airplane construction was as follows:

	Per cent
copper	4.31
iron	0.50
magnesium	1.87
silicon	0.25
manganese	0.36
aluminum	balance

What per cent of the material is aluminum?

17. The highest compression pressure allowable when using commercial gasoline is about 110 lb. per square inch. By treating a high-grade gasoline with tetraethyl in small amounts the compression pressure is increased to 130 lb. per square inch. What per cent of increase is this?

18. If the useful load of a large transport plane is 19,450 lb., and if the pay load is part of the useful load and is found to be 16,520 lb., what per cent of the useful load is the pay load?

19. By using a newly developed plastic, airplane designers have been able to reduce the weight of an airplane without impairing its strength. If the saving in weight by the substitution of such parts in a certain plane is 7% and the plane's weight would have been 7,500 lb., how many pounds lighter is the plane with the plastic parts?

20. The weight of the Boeing Clipper fully loaded is 84,000 lb. The fuel capacity is 5,400 gal. What per cent of the total loaded weight is the weight of the fuel?

21. A special 15-day round-trip rate of $28.60 is offered between Kansas City and Chicago. The regular round-trip fare between these cities is $38.70. What is the saving made by using the special rate? What is the per cent of saving?

22. A special $25.35 excursion rate is offered between Cincinnati and St. Louis. The regular round-trip fare between these points is $33.20. What is the saving made by using the excursion ticket? What is the per cent of saving?

23. The government tax on air-line fares is 5% of the regular fare. If the amounts of taxes on tickets are as follows, what are the fares: $3.46, $12.72, $8.95, $7.75, $10.24?

24. If at a given r.p.m. a propeller is 82% efficient and the motor develops 185 H.P., how many H.P. are actually usable?

If a propeller has an efficiency of 79% and the motor develops 216 H.P., how many H.P. are usable?

25. A general rule is to make fin area 12% of the wing area. (In gas-engine design it should be $7\frac{1}{2}$% of wing area.) What per cent of wing area is fin area in each of the following:

Wing Area *square feet*	*Fin Area* *square feet*
380	37
280	38
176	13

26. If the air speed of a plane is 160 m.p.h., a wind of 12 m.p.h. would be what per cent of the plane speed? 15 m.p.h.? 20 m.p.h.?

27. The United States Government tax on air-line fares is 5% of the fare. Find the tax on each of the fares below and the total cost of each ticket.

Albuquerque to Cincinnati	$74.25
Cincinnati to Detroit	14.25
Fort Wayne to Kansas City	30.25
Harrisburg to New York	11.00

28. A special educational fare is offered between Cincinnati and Dayton. The round-trip rate is $3.33. The regular round-trip rate is $5.66. Find the saving and the per cent of saving resulting from the use of the special fare.

29. An airplane repair job is estimated at a cost of $320. New parts will represent 35% of the cost and the profit will be 9%. How much is left for labor cost?

30. The round-trip fares on United States to Alaska Services are 10% off twice one-way fares. What are the round-trip fares corresponding to each of these one-way fares?

Nome to Fairbanks	$ 74.00
Seattle to Bethel	236.00
Flat to Galena	92.00
Juneau to Hot Springs	94.00

31. All Canadian air-line fares paid in Canada are subject to a 10% tax. Find the taxes on the following fares and the total cost of the ticket in each case: $156.10, $117.75, $108.35, $209.70, $24.40.

32. The gross weight of the DC-4 is 66,500 lb. The useful load is 20,000 lb. What per cent of the gross weight is the useful load?

33. When the air lines first took up the establishment of bases in the interior of Africa the proportion of employees ill with malaria and other tropical diseases was on the average 1 in 3. Since the companies have established medical centers this proportion has been reduced to 3%. What is the saving in man-hours per day of 8 hr. for a force of 120 men?

34. The Panair do Brazil opened four new air routes in 1941. This expansion increased the company's mileage by 3,515 and brought the total mileage to 9,382. What was the per cent of increase over 1940?

35. The *Atlantic Clipper* started from New York with a fuel load of 4,320 gal. It arrived at its destination with a reserve supply of 1,750 gal. How much fuel was used for the trip? What percentage of the fuel load was the reserve? The fuel capacity of the clipper is 5,400 gal. What per cent of the fuel capacity was the reserve in this case?

36. A plane started a flight with a fuel supply of 1,250 gal. It finished the trip with a reserve of 550 gal. If the line's regulations called for a reserve of 30% of the supply at the start, was this amount of reserve up to standard?

37. The NS-1 military primary trainer for the United States Navy has an empty weight of 2,080 lb. and a gross weight of 2,800 lb. What per cent of the gross weight is the useful load?

38. There were 17,351 certified planes on January 1, 1941, compared with 12,829 the previous year. What was the percentage of increase?

39. Below are figures on nonmilitary aircraft in 5 states for 1941 and the per cent of increase over 1940. Find the number of planes of each state in 1940.

	1941	*Per Cent Increase*
Alabama	119	35.2
Connecticut	198	25.3
Delaware	89	43.5
Illinois	992	13.5
Kentucky	118	32.6

40. The passenger revenue received for a flight was $650.25. How much of this was United States Government tax, which is 5% of the fare?

41. The useful load and maximum gross weight are given for each of two types of transport plane. What per cent of the gross weight is the useful load in each case? Which has the higher per cent of useful load? What per cent?

	A	*B*
Useful load	7,900	14,975
Maximum gross weight	24,150	49,000

42. Pay load is found by the following formula:

$$\text{per cent} = \frac{\text{pay load}}{\text{gross weight}} \times 100$$

Find what per cent the pay load is of the gross weight in each of the following cases:

Gross Weight *pounds*	*Pay Load* *pounds*
1,565	190
6,250	1,020
2,026	251
4,150	675

43. The gross weight of a Boeing Model 314 is 82,500 lb. Its pay load is 10,000 lb. Find the per cent of pay load.

44. If the air speed of a plane is 160 m.p.h., a 10 m.p.h. wind is what per cent of the air speed? a 12 m.p.h. wind? a 14 m.p.h. wind?

45. Suggestions from employees as to how service could be improved were received by the suggestion board of a large airline at the rate of 33 per month in 1940. In 1941 suggestions were received at the rate of 175 per month. What is the per cent of increase?

46. Of the original enrollees in a United States Army Air Corps class 95% were graduated. There were 91 graduates. How many enrolled?

47. The newest engines in the Boeing Clippers are rated at 1,600 H.P. each, the engines they replaced at 1,500 H.P. What is the per cent of increase in H.P.?

48. In the first nine months of 1941, 13,374,022 lb. of air express were carried as compared with 8,647,457 lb. carried during the similar period in 1940. What was the per cent of increase in weight of express business? (State result to the nearest per cent.)

49. A certain plane weighs 9,430 lb. when fully loaded and 6,250 lb. empty. What per cent of the total weight is the weight of the load?

50. A device for weighing clippers has been developed which determines the weight to within $\frac{1}{2}$ of 1%. What is the possible error in weighing a load of 15,000 lb.?

51. The return schedule calls for departure from Nome at 1155 and arrival in Fairbanks at 1620. What is the average ground rate in miles per hour of the return trip? The distance between Fairbanks and Nome is 540 mi.

52. A basic alloy of stainless steel used in airplane construction is called "18-8." Its composition is:

	Per cent
chromium	18
nickel	8
carbon	.06–.15

The rest is iron.

If the carbon content of a sample was 0.975%, what was the per cent of iron in the sample?

53. An aluminum solder is composed of 75.5 parts tin, 18 parts zinc, 2.5 parts aluminum. What is the percentage of each?

54. If the cost of an airplane engine is known to be $1,200, what is its rated horsepower, if it is known that the cost per rated horsepower is $15?

55. A battery solution is made up of sulphuric acid and water. If there are 360 cc. of the solution and 12% of it is sulphuric acid, how many cubic centimeters of sulphuric acid are there?

56. A sample of nickel steel contains 23.5% nickel and 0.09% carbon. How much carbon and how much nickel are there in 2,400 lb. of nickel steel?

57. At a certain naval air station 9% of the men are on leave, 6% are in the hospital, and 425 are left on active duty. What is the full numerical strength of this unit?

CHAPTER 14

EQUATIONS

1. The rate going from A to B was 125 m.p.h. The rate returning was 110 m.p.h. The flying time required for the round trip was 4 hr. Find the distance from A to B. Find the average rate for the trip.

2. The rate going from A to B was 120 m.p.h. and the rate returning was 160 m.p.h. The round trip required 7 hr. flying time. What is the distance from A to B? What was the average ground rate?

3. A plane flies from A to B and returns in 3 hr. The rate going is 155 m.p.h. and that returning is 160 m.p.h. How far is it from A to B?

4. The fare from Columbus to Pittsburgh is $9.10. The passenger revenue for a flight was $72.80. There were 10 passengers, some traveling at half fare and the rest at full one-way fare. How many of each were there?

5. The passenger revenue received by the air line for a flight from Chicago to New York amounted to $620.25. There were 15 passengers. Part of them paid the one-way fare of $44.95, and the rest used round-trip tickets costing $80.90. How many had one-way tickets?

6. An air line received $288.75 in fares for 20 passengers on a certain trip. Part of these were at full fare and part at half fare. If the full rate was $17.50, how many traveled at half fare?

7. The passenger revenue received for a flight from Baltimore to Greenville, South Carolina, was $509.90. Ten passengers had one-way tickets and the rest had round-trip tickets at $53.35. The one-way rate is $29.65. How many passengers used the round-trip tickets?

8. The fare from Cincinnati to Dayton is $3.15. Some passengers had full one-way tickets and the rest used special round-

trip tickets priced at $3.33. The revenue amounted to $27.23. There were 11 passengers on the trip. How many paid full fare?

9. The total passenger revenue for a trip from New York to Miami was $1,108.15. Ten passengers made the whole trip at the one-way rate, and 10 other passengers made various parts of the trip. What was the average revenue from each passenger going only part way? (The fare from New York to Miami is $71.75.)

10. On a flight in South America the passenger revenue was $1,180.66. Some passengers traveled at $\frac{1}{3}$ fare, 2 at $\frac{2}{3}$ fare, and 6 at full fare. How many traveled at $\frac{1}{3}$ fare if the full fare for the trip was $136.23?

11. A plane flew from *A* to *B* against a wind of 20 m.p.h. velocity and made the return trip with a wind of the same velocity. The time required for one way was 4 hr. and for the return trip 3 hr. What was the air speed of the plane, and what is the distance between *A* and *B*?

12. A plane flew from *A* to *B*, a distance of 800 mi., in 6 hr. On the return trip with the same engine speed the plane took only 4 hr. Find the average speed of the plane and the velocity of the wind.

13. If an airplane flies from Albany to New York against a south wind at a ground speed of 120 m.p.h. and its air speed is 140 m.p.h., what is the rate of the wind? If the distance between airports is 138 mi., how much time is required for the trip?

14. An airplane flying at its cruising air speed of 160 m.p.h. is held back by a head wind and takes 3 hr. to complete a flight of 400 mi. What is the rate of the wind?

15. A plane flying north at an average air speed of 150 m.p.h. is aided by a tail wind of 20 m.p.h. velocity. How long will it take the plane to complete a trip of 550 mi.?

16. A carrier steams for 2 hr. at its regular rate of speed and then proceeds for 3 hr. at half speed. Find the regular speed of the carrier if it goes 98 mi. in all, under the conditions stated.

17. In making a trip of several hundred miles the pilot of a plane took on 24 gal. of gas and 7 qt. of oil. At a later time his purchase was 18 gal. of gas and 3 qt. of oil. The first time his

bill was \$7.53. The next time it was \$4.83. What was the price per gallon of the gas and per quart for the oil?

18. The owner of a small plane used 30 gal. of gas and 5 qt. of oil for one trip, and another time he used 25 gal. of gas and 3 qt. of oil. His bill the first time was \$7.95 and the second time \$5.67. If the gas and oil prices were the same both times, how much did he pay per gallon for gas and per quart for oil?

19. A buyer in the steward's department of an air line finds that 50 doz. eggs and 10 lb. of butter cost \$34.50. At the same rates per dozen and per pound 34 doz. eggs and 20 lb. of butter cost \$29.40. What is the price per dozen of eggs and the price per pound of butter?

20. An airplane trip cost Mr. Smith \$80.41. The cost of ground transportation to and from the airports was \$1.50. The government tax on the plane fare is 5% of the scheduled fare. What was the scheduled airplane fare?

21. Two planes start from the same airport at the same time and fly in opposite directions. After 4 hr. of flying the planes are 1,160 mi. apart. If one plane flies 30 m.p.h. faster than the other, what is the rate of the slower plane?

22. Two planes start from the same airport at the same time and fly in opposite directions. The rate of one plane is 10 m.p.h. more than that of the other. After 4 hr. the planes are 1,240 mi. apart. What is the rate of each plane?

23. A plane can fly 425 mi. in 2 hr. 30 min. with the wind, and 325 mi. in the same time against the wind. Find the air speed of the plane and the rate of the wind.

24. A plane flies for 3 hr. at a uniform speed and for 4 hr. at a speed 20 m.p.h. greater. Find the original speed if the distance traveled was 850 mi.

25. A plane flew 3 hr. at 170 m.p.h., and then reduced speed because of engine trouble, and finished the trip in 2 hr. All together the plane flew 780 mi. What was the reduced rate of flying?

26. A plane flies from Los Angeles to Seattle—an airway distance of 1,043 mi.—at a certain ground speed for the first 2 hr. During the next 3 hr. its speed is reduced 20 m.p.h. It completes the journey in another 2 hr., traveling at the original speed. Find the original ground speed.

27. A plane flies from Detroit to Sault Sainte Marie, an air-

way distance of 347 mi., with the wind, requiring 2 hr. for the trip. Returning, it flies against the wind and requires 2 hr. 30 min. What is the air speed of the plane and the rate of the wind?

28. A plane flying from New York to Pittsburgh, a distance of 324 mi., takes 2 hr. 40 min. for the trip. The return trip is made in 2 hr. 10 min. Assuming that the plane maintained the same average air speed both ways, and that the difference in time was due wholly to the wind, find the air speed of the plane and the rate of the wind.

29. Two planes, one leaving Montreal and the other New York at the same time, pass each other at a point 160 mi. north of New York, in 1 hr. 15 min. The cities are 332 mi. apart. What is the ground rate of each plane, and how long will it take each to make the whole one-way trip?

30. The faster of two planes requires 1 hr. 45 min. to fly from Buffalo to Pittsburgh, a distance of 215 mi. If the difference between the ground speeds of the planes is 5 m.p.h., what is the ground speed of the slower plane?

31. If a military plane of a certain type is flying at an average rate of 180 m.p.h., how long will it take an interceptor to overtake it if the first plane has a start of 2 hr. and the interceptor flies at a rate of 225 m.p.h.?

32. A blimp on patrol duty and flying a definite course is to be intercepted by a patrol plane. If the blimp has a start of 5 hr. and is making 60 m.p.h., how fast will the patrol need to travel in order to overtake the blimp in 3 hr.? Solve graphically.

CHAPTER 15

DESIGN PROBLEMS

Wing Loading

THE wing loading of a plane is defined as the number of pounds of gross weight that each square foot of the wing must support in flight. To find the wing loading of a plane divide the gross weight by the wing area.

Expressed as a formula this becomes:

$$\text{wing loading} = \frac{\text{gross weight}}{\text{wing area}}$$

1. Using the formula, supply the wing-loading values in the following. *(Do not write in this book.)*

Gross Weight	*Wing Area*	*Wing Loading*
4,553	260.6	
5,000	270.0	
3,360	250.0	

2. The wing area of the PT-1 is 297 sq. ft. The wing loading is 9.4 lb. per square foot. What is its gross weight?

3. The wing loading of the Ryan Seaplane STM-S2 is 14.7 lb. per square foot. The gross weight is 1,828 lb. Find the wing area.

4. The Republic P-35A has a wing area of 220 sq. ft. Its wing loading is 27.1 lb. per square foot. Find its gross weight.

To find gross weight of a plane multiply the wing loading by the wing area.

5. Find the gross weights of planes having the following wing loadings and wing areas.

Plane	*Wing Loading*	*Wing Area*
A	14.5	346
B	17.8	420
C	22.5	540

6. Find wing loadings from data given:

Plane	*Gross Weight*	*Wing Area*
A	16,500	495
B	18,250	850
C	40,000	1,055

7. If the gross weight of a plane is given as 13,500 lb. and its wing loading as 16.2 lb., what is its wing area?

8. Find the wing area of a plane having a gross weight of 25,000 lb. and a wing loading of 25.5 lb.

Power Loading

The power loading of a plane is found by dividing the gross weight by the horsepower. It is important that plane designers know the power loading for a given weight when they are designing planes for definite purposes. The formula for power loading is:

$$\text{power loading} = \frac{\text{gross weight}}{\text{horsepower}}$$

What is the effect of increasing the horsepower if the gross weight remains the same? What is the effect of increasing the gross weight but keeping the horsepower the same?

1. Find the power loading for each of the following planes:

Plane	*Gross Weight*	*Horsepower*
A	1,215	44
B	6,200	435
C	3,950	325

2. The gross weight of the new Cloud Cruiser is 3,200 lb. The power loading is 12.8 lb. per horsepower. What is the horsepower?

3. Find the power loading for each of the following:

Plane	*Gross Weight*	*Horsepower*
A	16,500	750
B	18,252	800
C	40,000	1,100

4. Find the power loading of each of following planes:

	Model	*Gross Weight*	*Horsepower*
Consolidated Aircraft	28	30,500	2,400
Consolidated Aircraft	32	40,000	4,800
Cunningham Hall	PT-6F	4,550	365
Grumman Aircraft	JRF-2	8,000	800
Douglas Aircraft	DC-3	25,200	2,000
The Glenn L. Martin Co.	PBM-1	40,000	2,700

5. Substitute the values given here to obtain the power loading of a Martin B 26 bomber.

Gross weight	26,625
Horsepower	3,700

6. Find the power loading of a Luscombe all-metal trainer whose gross weight is 1,200 lb. and whose horsepower is 65.

7. Find the gross weight of the Franklin 90 AF if the wing area is 132.2 sq. ft. and the wing loading is 12.2 lb. per square foot.

gross weight = empty weight + useful load

1. The Cloud Cruiser has an empty weight of 1,950 lb. and a gross weight of 3,200. What is its useful load?

What is the ratio of the useful load to the gross weight? Express this ratio as a decimal.

2. Express the ratio of useful load to empty weight of each of the following as a per cent:

Plane	*Useful Load*	*Empty Weight*
A	950	1,560
B	428	580
C	8,950	16,100
D	875	1,456

3. The structural weight per pound carried is found by dividing the empty weight by the useful load. Find the structural weight per pound of Planes A, B, C, D in the preceding problem.

The landing speed of an airplane is affected by changing its gross weight. A formula that shows the relationship between landing speeds and gross weight is:

$$\frac{V_1}{V_2} = \sqrt{\frac{W_1}{W_2}}$$

$V_1 =$ first velocity

$W_1 =$ gross weight

$V_2 =$ new velocity

$W_2 =$ new gross weight

1. An airplane weighing 2,500 lb. lands at 50 m.p.h. With 500 lb. more load, what is the landing speed?

Solution:

$$\frac{50}{V_2} = \sqrt{\frac{2500}{3000}}$$

$$\frac{50}{V_2} = \sqrt{\frac{5}{6}}$$

$$V_2 = \frac{50}{\sqrt{\frac{5}{6}}}$$

$$V_2 = 54.8 \text{ m.p.h.}$$

2. An airplane weighing 6,000 lb. flies at 110 m.p.h. With 500 lb. more load, what should be the air speed at the same angle of attack? (Work this just as you would if you were finding a new landing speed as in problem 1.)

3. The Douglas DC-3 weighs 24,400 lb. and has a minimum speed of 67 m.p.h. After it has used 430 gal. of fuel, what is its minimum speed?

4. The gross weight of the Boeing 307-B is 45,000 lb. with a full fuel supply. Its landing speed at this weight is 70 m.p.h. What is its landing speed after it has burned 500 gal. of gasoline?

5. The gross weight of the Boeing A 314 is 84,000 lb. Its landing speed is 70 m.p.h. Find its landing speed after it has burned up 4,000 lb. of fuel.

6. The gross weight of the Beechcraft 18-S is 7,500 lb. Its

landing speed is 61 m.p.h. What is its landing speed at a weight 250 lb. less than its gross weight?

7. The gross weight of the Douglas DC-4 is 52,000 lb. Its landing speed is 78 m.p.h. After it has used 650 gal. of gasoline, what is its landing speed?

8. An airplane lands at 50 m.p.h. when the gross weight is 4,000 lb. What is its landing speed with 600 lb. more load?

9. What would be the landing speed of the plane in problem 8 if its gross weight were 3,000 lb.?

Designers need to figure the landing speed for a change in wing area if the landing speed for a certain wing area is known.

A formula for finding the new landing speed for a new wing area is:

$$V_2 = V_1 \sqrt{\frac{S_1}{S_2}}$$

V_1 = given landing speed

V_2 = new landing speed

S_1 = given wing area

S_2 = new wing area

1. An airplane lands at 45 m.p.h. when the wing area is 300 sq. ft. What is the landing speed with 50 sq. ft. less wing area?

Solution:

$$S_2 = 300 - 50$$

$$S_2 = 250$$

$$V_2 = 45\sqrt{\frac{300}{250}}$$

$$V_2 = 49.5 \text{ m.p.h.}$$

2. An airplane with 500 sq. ft. wing area lands at 57 m.p.h. With 100 sq. ft. additional area, what is its landing speed?

A formula for finding the required horsepower for a change in wing area if the horsepower required for a given wing area is known, is:

$$H.P._2 = H.P._1\sqrt{\frac{S_1}{S_2}}$$

$H.P._1$ = original horsepower

$H.P._2$ = new horsepower

S_1 = original wing area

S_2 = new wing area

1. An airplane has a wing area of 350 sq. ft. and requires 80 H.P. at a certain angle of attack. With 50 sq. ft. additional area but with the total weight unchanged, what is the power needed to fly at the same angle of attack?

Solution:

$$H.P._2 = H.P._1\sqrt{\frac{S_1}{S_2}}$$

$$H.P._2 = 80\sqrt{\frac{350}{400}}$$

$$H.P._2 = 74.9$$

2. A plane with a wing area of 252.7 sq. ft. requires 100 H.P. at a certain angle of attack. With 100 sq. ft. more wing area, and with the total weight unchanged, what power is needed at the same angle of attack?

3. A plane with a wing area of 316 sq. ft. requires 106 H.P. for a certain angle of attack. With 60 sq. ft. less wing area, what power is needed for the plane at the same angle of attack if the total weight of the plane remains unchanged?

4. A plane with a wing area of 650 sq. ft. requires 250 H.P. for a certain angle of attack. With 75 sq. ft. more wing area, but with the total weight unchanged, what power is needed?

5. An airplane with wing area of 172 sq. ft. requires 300 H.P. to fly at a certain angle of attack. With 40 sq. ft. added to the wing, but with the same weight, what power is needed?

6. An airplane has a wing area of 250 sq. ft. and requires 500 H.P. With 50 sq. ft. less wing area but with the same total weight, what power is needed at the same angle of attack?

7. Using the formula $H.P._2 = H.P._1 \sqrt{\frac{S_1}{S_2}}$ complete the following table. (*Copy the table. Do not write in this book.*)

Plane	*Wing Area*	*Different Wing Area*	*Horsepower Given*	*Horsepower Required*
Aeronca	169	175	65	
Culver	120	110	80	
Luscombe	140	155	65	
Piper (trainer)	178.5	165	65	
Ryan S-C	202	225	145	
Stinson	155	165	90	
Waco	243.6	250	220	

You have solved problems in which you were given the gross weight and velocity of a plane and you were required to find the velocity if the gross weight were changed. Also there were problems dealing with a change in velocity that results from changing the wing area.

Now we shall consider a problem in which the gross weight and wing area both are changed.

Example:

If the gross weight of a plane is 1,450 lb., its wing area is 187 sq. ft., and its landing speed is 55 m.p.h., find its landing speed if it were to have 13 sq. ft. more wing area and 250 lb. more weight.

Solution:

First we could solve for the change in gross weight.

$$V_2 = V_1\sqrt{\frac{W_2}{W_1}}$$

$$V_2 = 55\sqrt{\frac{1700}{1450}}$$

$$V_2 = 55 \times 1.08$$

$$V_2 = 59.4$$

The landing speed has been increased by adding to the gross weight.

Now we take the landing speed 59.4, which we have just found, and determine the landing speed for the change in wing area.

$$V_2 = V_1\sqrt{\frac{S_1}{S_2}}$$

$$V_2 = 59.4\sqrt{\frac{187}{200}}$$

$$V_2 = 59.4 \times .95$$

$$V_2 = 56.4$$

It would be easier to combine the two solutions like this:

$$V_2 = V_1\sqrt{\frac{W_2 \times S_1}{W_1 \times S_2}}$$

$$V_2 = 55\sqrt{\frac{1700}{1450} \times \frac{187}{200}}$$

$$V_2 = 55 \times 1.025$$

$$V_2 = 56.4$$

1. An airplane weighing 6,000 lb. has a wing area of 260 sq. ft. and a landing speed of 55 m.p.h. What is the landing speed with 400 lb. more load and 50 sq. ft. less wing area?

2. An airplane weighing 5,000 lb. has a wing area of 270 sq. ft. and a landing speed of 50 m.p.h. What is the landing speed with 500 lb. more load and 60 sq. ft. more area?

3. An airplane weighing 6,500 lb. has a wing area of 360 sq. ft. and a landing speed of 55 m.p.h. What is the landing speed with 500 lb. more load and 75 sq. ft. more area?

4. An airplane weighing 7,000 lb. has a wing area of 340 sq. ft. and a landing speed of 61 m.p.h. What is the landing speed with 500 lb. less load and 75 sq. ft. less area?

Find the ratio of horizontal tail surface to wing area, in each of the following. *(Copy the table. Do not write in this book.)*

	Horizontal Tail Surface	*Wing Area*	*Ratio*
Aeronca	25.14	169	
Piper Cub	25.29	179	
Porterfield	21.57	168	
Luscombe	21.75	140	
Rearwin	27.16	166	

If a designer decides upon a certain horsepower for an engine and a definite power loading, he can determine the gross weight (total weight) of a plane.

Example:

Find the possible gross weight a plane will have if it has a 65 H.P. engine and a power loading of 17 lb. per horsepower.

Solution:

$$\text{gross weight} = \text{H.P. times power loading}$$

$$65 \times 17 = 1{,}105 \text{ lb.}$$

1. Complete the following table. (*Copy the table. Do not write in this book.*)

Plane	*Horsepower*	*Power Loading*	*Possible Gross Weight*
65-C	65	17.7	
P-2	100	16.5	
14-9	90	19.4	
415-C	65	18.1	
Aircar-1	90	18.9	

CHAPTER 16

CENTER OF GRAVITY

PROBLEMS having to do with the center of gravity of a plane and the center of lift of a wing are of great importance to designers and operators of full-size and model planes built for flying. The solutions of some of these problems depend on certain theorems and principles of plane geometry, some of which are explained in this chapter. In many plane-geometry textbooks the proof of the theorem: "The medians of a triangle are concurrent in a point two-thirds of the distance from any vertex to the midpoint of the opposite side" is incomplete or omitted. The centroid of a wing section or a fuselage of a model plane is referred to frequently in books on model aircraft, and with this new importance of the centroid of plane figures it seems wise to give a proof in this section of the theorem stated above.

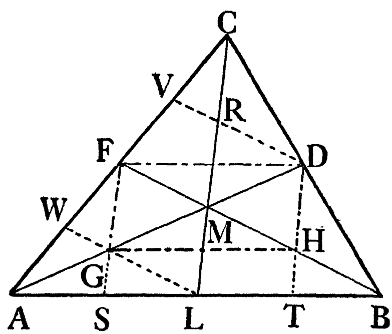


Fig. 1

Construction

1. Draw medians AD and BF.
2. Draw FD, and GH connecting the midpoints of AM and MB.
3. Draw FG and DH and extend to S and T.
4. Draw CM and extend to L.
5. Draw DV through the midpoint R of CM.
6. Draw LG and extend to W.

PROOF

Steps	*Reasons*
1. $FDHG$ is a parallelogram	1. FD joins the midpoints of 2 sides of triangle ABC. GH joins midpoints of 2 sides of triangle AMB. FD is parallel and $= \frac{AB}{2}$. GH is parallel and $= \frac{AB}{2}$.
2. $AG = GM = MD$ and $BH = MH = MF$	2. Construction, diagonals of a parallelogram bisect each other, and substitution.
3. $AS = SL = LT = BT$	3. A line joining midpoints of 2 sides of a triangle is parallel to the base, lines cutting off equal segments on one transversal cut off equal segments on every transversal, and substitution.
4. L is the midpoint of AB	4. $AS + SL = LT + BT$. Step 3, and addition.
5. GL is parallel to BM and DR is parallel to BM.	5. A line joining midpoints of 2 sides of a triangle is parallel to the third side.
6. $AW = WF = FV = VC$	6. Parallel lines cutting off equal segments on one transversal cut off equal segments on every transversal, and substitution.
7. $CR = RM = ML$	7. Same as reason 6.
8. The medians AD and BF meet in M and the line CL, which passes through M, bisects AB.	8. Same as reason 4.

The three medians are concurrent and M is two-thirds the distance from each vertex to the midpoint of the opposite side.

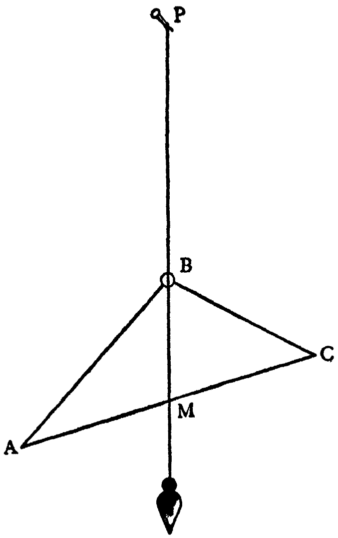


Fig. 2

Locate the centroid of a triangle cut from cardboard of uniform thickness by suspending it at each vertex in succession from a point. Let a plumb line from point *P* cut the triangle in *BM*. If this line has been marked with chalk, the median *BM* will be marked on the triangle. The three median lines will be concurrent.

Questions: What is the relationship between areas of triangles *ABM* and *BMC?* Discuss the relationship between the other pairs of triangles formed by medians.

To determine the centroid of the lateral area of a model plane, cut out a model profile of the plane from a sheet of cardboard. Suspend a plumb line from a point *P* so that it passes through *A*, a point from which the profile cut-out is suspended. Suspend the profile from another point, such as *B*, and mark the line of intersection of *PBB*[1] with the line of intersection through *A*. Then suspend the profile from a third point to test whether the three lines are concurrent.

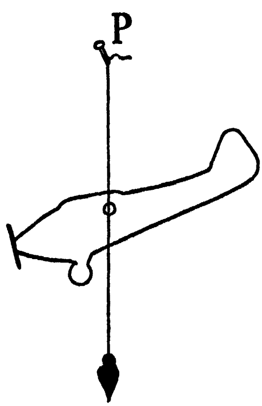


Fig. 3

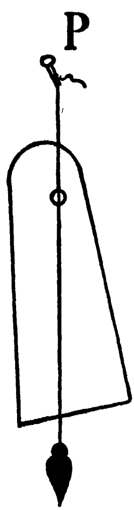


Fig. 4

Test a wing pattern in the same way.

Problem: To locate the centroid of any trapezoid.

Connect the midpoints of the bases. Find the centroid of each triangle. Join the centroids of the triangles. The point of intersection of the line joining the centroids and the line joining the midpoints of the bases intersect at the required point.

Construct a trapezoid of cardboard, locate the centroid as described, and test the balance of the constructed figure.

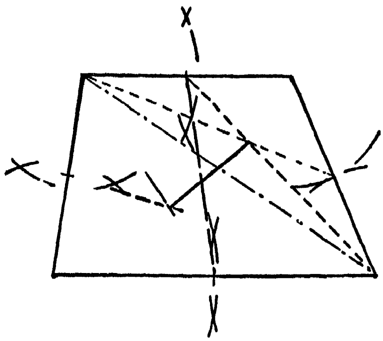


Fig. 5

For practical purposes the center of pressure of a wing is considered as concentrated along the mean aerodynamic chord of the wing. Figure 6 shows how this mean aerodynamic chord may be located on a plan of a wing by geometric construction. In the figure the line *a*, which is the root chord of the wing or wing section, is extended through *U* the distance *b*, which is the tip chord of the wing. (As the wing tip is curved in this case, *b* is the chord somewhat in from the extreme tip, and is taken this way to compensate for the curvature.) The line *SR* is made up of *b* and *a*. *NR* is drawn, and *YW*, which joins the midpoints of the tip and root chords. Next *TV* is drawn through *L* perpendicular to *YW*. *TV* is the mean aerodynamic chord (M.A.C.). The point *L* is the centroid of the wing.

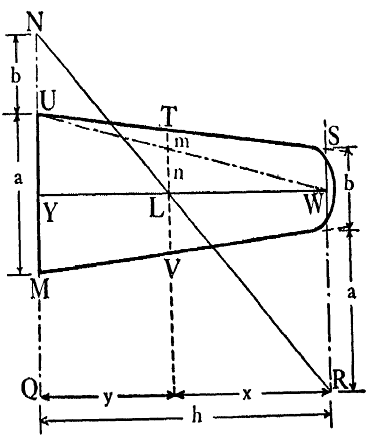


Fig. 6

A formula for finding the mean aerodynamic chord is:

$$M.A.C. = \frac{2}{3}\left(a + b - \frac{ab}{a+b}\right)$$

A proof of this formula is as follows:

Steps	*Reasons*
1. $\dfrac{NL}{LR} = \dfrac{\frac{a}{2} + b}{\frac{b}{2} + a}$	1. Corresponding sides of similar triangles are in proportion.
2. $\dfrac{n}{\frac{a}{2}} = \dfrac{2a + b}{3(b+a)}$	2. Same as reason 1.
3. $\dfrac{m}{\frac{b}{2}} = \dfrac{2b + a}{3(b+a)}$	3. Same as reason 1.
4. $\dfrac{2m}{b} = \dfrac{2b + a}{3(b+a)}$	4. Multiplication.
5. $3(b + a)2n = 2a^2 + ab$	5. From step 2.
6. $3(b + a)2m = 2b^2 + ab$	6. From step 4.
7. $6(b + a)(m + n) = 2(a^2 + ab + b^2)$	7. From steps 5 and 6.
8. $6(m + n) = \dfrac{2(a^2 + ab + b^2)}{b + a}$	8. From step 7.
9. $m + n = \dfrac{1(a^2 + ab + b^2)}{3(b + a)}$	9. Division.
10. $TV = 2(m + n)$ $TV = \dfrac{2}{3} \cdot \dfrac{(a^2 + ab + b^2)}{b + a}$ or $\dfrac{2}{3}\left(a + b - \dfrac{ab}{a+b}\right)$	

In machine design it is sometimes necessary for the layout man to find the centroid of a trapezoid. To do this he would make use of the following formula:

$$y = \frac{h(a + 2b)}{3(a + b)}$$

By referring to Figure 6 and the proof of the formula for finding the mean aerodynamic chord we shall see how this formula is derived.

$\frac{x}{h} = \frac{n}{\frac{a}{2}}$	Corresponding sides of similar triangles
$\frac{x}{h} = \frac{2a + b}{3(a + b)}$	Substitution
$x = \frac{h(2a + b)}{3(a + b)}$	Solving for x

$$y = h - x$$

$$y = h - \frac{h(2a + b)}{3(a + b)}$$

$$y = \frac{3ah + 3bh - 2ah - bh}{3(a + b)}$$

$$y = \frac{h(a + 2b)}{3(a + b)}$$

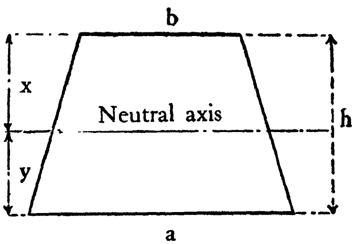


Fig. 7

The center of gravity of the trapezoid falls on a line through a point that is at the distance y from the base a. By substituting values for a, b, and h which can be measured, it is possible to find the value of y.

Example:

Given $a = \frac{5}{8}$ in., $b = \frac{3}{8}$ in., and $h = 1\frac{1}{4}$ in. Find y.

Solution:

$$y = \frac{1\frac{1}{4}(\frac{5}{8} + \frac{3}{4})}{3(\frac{5}{8} + \frac{3}{8})} = \frac{\frac{5}{4} \cdot \frac{11}{8}}{3} = .573$$

Given a, b, h, find y in each of the following. *(Copy the table. Do not write in this book.)*

	a inches	b inches	h inches	y inches
1.	$\frac{7}{8}$	$\frac{1}{4}$	3	
2.	$\frac{5}{8}$	$\frac{5}{16}$	$2\frac{1}{2}$	
3.	$\frac{3}{8}$	$\frac{1}{8}$	$\frac{7}{8}$	

	a inches	*b* inches	*h* inches	*y* inches
4.	$\frac{1}{2}$	$\frac{3}{16}$	$1\frac{1}{8}$	
5.	$\frac{3}{4}$	$\frac{3}{8}$	$1\frac{3}{8}$	
6.	$\frac{5}{8}$	$\frac{3}{16}$	1	
7.	.375	.125	1.5	
8.	.575	.375	1.25	

Find the mean aerodynamic chord for tapered wings having the following *a* and *b* lengths.

	a	*b*
1.	72 in.	30 in.
2.	4 ft. 2 in.	2 ft. 3 in.
3.	5 ft. 3 in.	3 ft. 2 in.
4.	66 in.	28 in.
5.	55 in.	20 in.
6.	75 in.	34 in.
7.	6 ft. 1 in.	3 ft. 8 in.
8.	48 in.	22 in.

Figure 8 illustrates forces acting about a point of balance *F*. What weight is required to balance the force exerted by 500 lb. attached 2 ft. from *F*, which is the fulcrum, if the weight required is to be attached 18 ft. to the right of *F*? If we multiply 500 by 2 we find the force acting to the left of the fulcrum. To find the weight required to maintain a balance, divide 1,000 by 18. The required weight is found to be 55.6 lb.

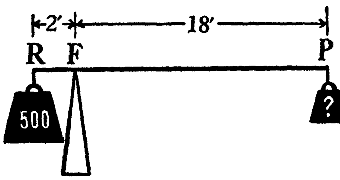


Fig. 8

1. What weight is required to balance a weight of 15 lb. 7 in. from the fulcrum if the unknown weight is to be placed 4 in. from the fulcrum?

2. Find the weight required to balance 6 kg. 4 in. from the fulcrum if the second weight is applied 10 in. from the fulcrum.

3. What weight is required to balance 10 lb. 15 in. from the fulcrum if the second weight is located 4 in. from *F*?

4. Weights of 25 lb. and 7 lb. are to be placed in balance

on a bar of uniform weight. Find the location of the fulcrum if the weights are to be 25 in. apart at the ends of the bar.

5. A weight of 45 lb. is attached to one end of a bar 2 ft. 6 in. long and a weight of $11\frac{1}{2}$ lb. is attached to the other end of the bar. Where must the fulcrum be placed in order to have the forces balanced?

Before an airplane is built a detailed estimate of all of the parts and loads to be carried must be made. The position of the center of gravity of each of these weights is determined. It can be determined just where the center of gravity of the airplane will be, and whether it is in correct location with respect to the wings.

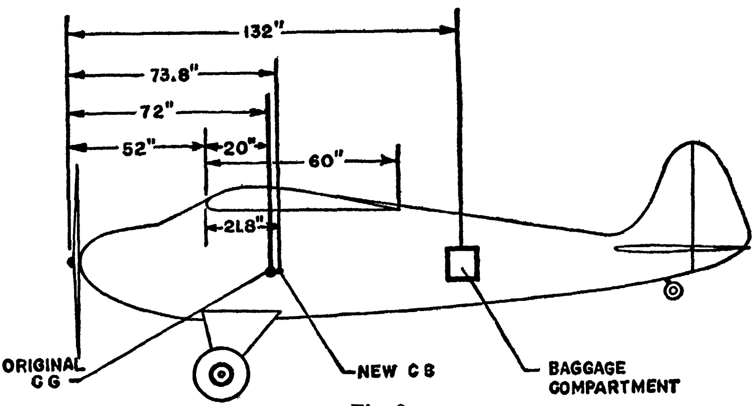


Fig. 9

Figure 9 shows the location of the center of gravity of a plane weighing 1,300 lb. fully loaded. Additional baggage weighing 40 lb. is placed in the baggage compartment 132 in. from the nose. The center of gravity is 72 in. from the nose.

By placing the baggage as he did the pilot has moved the center of gravity enough to make the flying of the plane dangerous. To insure straight flight at a constant speed requires that all forces be exactly balanced.

The distance from the fulcrum to the point of attachment of a weight is called the *arm* or *moment arm*. The weight times the length of the arm gives the *moment* of the force. If the weight is in pounds and the distance in inches, the moment is in pound-inches. If the distances are in inches and the weights

in kilograms the forces are called inch-kilos. Inch-kilos are used by some of the air lines in figuring the moments about the center of gravity of a plane.

In determining the center of gravity of the fully loaded plane it is necessary to find the weight of the gasoline and that of the tank.

1. A plane is designed to have a cruising radius of 400 mi. What weight of gasoline will be needed?

If the cruising speed of the plane is 100 m.p.h., the number of hours the plane will fly, starting with a full tank, is $400 \div 100 = 4$ hr.; 25% additional flying time is needed for safety.

$$4 \text{ hr.} + 25\% \text{ of } 4 \text{ hr.} = 5 \text{ hr.}$$

If the engine uses about 4 gal. per hour at cruising speed, the number of gallons needed for 5 hr. is

$$5 \times 4 = 20 \text{ gal.}$$

A gallon of gasoline weighs about 6 lb. Therefore 20 gal. will weigh

$$20 \times 6 \text{ lb.} = 120 \text{ lb.}$$

If the gas tank weighs 8 lb., the weight of the full tank will be 128 lb.

2. What is the weight of a tank of gasoline sufficient for a cruising radius of 500 mi. at 95 m.p.h., if the consumption is $4\frac{1}{2}$ gal. per hour, the allowance for safety 25%, and the weight of the gasoline tank 9 lb.?

CHAPTER 17

OTHER FORMULAS

IN OTHER sections of this book we have used various formulas that are important in aviation. There are many others, some of which are introduced and applied in this chapter.

HORSEPOWER

One horsepower (H.P.) is defined as the power necessary to lift 1 lb. 33,000 ft. in 1 min. or 550 ft. in 1 sec.

Example:

What horsepower is required to lift 1,500 lb. 30 ft. in 20 sec.?

Solution:

$$1{,}500 \times 30 = 45{,}000 \text{ ft. lb.} \quad (1{,}500 \text{ lb., } 30 \text{ ft.})$$

$$\frac{45{,}000}{20} = 2{,}250 \text{ ft. lb. per sec.}$$

$$\frac{2{,}250}{550} = 4.1 \text{ H.P.}$$

1. What horsepower is required for an airplane weighing 2,500 lb. in climbing 1,000 ft. in 1 min.?
2. What horsepower is required for a DC-3 weighing 24,000 lb. to climb 500 ft. in 1 min.?
3. Find the horsepower required for a plane weighing 10,000 lb. to climb 1,500 ft. in 1 min.
4. Find the horsepower required for a plane weighing 8,500 lb. to climb 875 ft. in 1 min.
5. What horsepower is required for an airplane weighing 1,750 lb. to climb 750 ft. in 1 min.?

The formula for the horsepower required to fly an airplane is:

$$H.P._r = \frac{D_t V}{375}$$

$H.P._r =$ horsepower required

$D_t =$ total drag of the airplane in pounds

$375 =$ horsepower constant when velocity is in miles per hour

$V =$ velocity in miles per hour

6. Find H.P.$_r$ when $D_t = 405$ lb., $V = 130$ m.p.h.
7. Find H.P. required when $D_t = 510$ lb., $V = 140$ m.p.h.
8. Find H.P. required when $D_t = 385$ lb., $V = 128$ m.p.h.
9. Find the H.P. required when $D_t = 150$ lb., $V = 80$ m.p.h.

The horsepower excess is the difference between the horsepower available and the horsepower required. Horsepower excess is used in climbing to higher altitudes.

H.P. excess $\times$ 33,000 = ft. lb. per min. excess power

velocity of climb = ft. lb. per min.

$$V = \frac{\text{ft. lb. per min. excess power}}{\text{gross wt. in lb.}}$$

10. The weight of a plane = 2,000 lb., H.P. available = 85, H. P. required = 42. Find the velocity of climb.

H.P. excess = 85 − 42

H.P. excess = 43

43 $\times$ 33,000 = 1,419,000 ft. lb. per min.

$$\text{velocity of climb} = \frac{1{,}419{,}000}{2{,}000}$$

velocity of climb = 709.5 ft. per min.

11. Find the velocity of climb if H.P. available = 80, H.P. required = 42, weight of plane = 1,850.

12. Find the velocity of climb if H.P. available = 115, H.P. required = 75, weight of plane = 2,150 lb.

13. Find the velocity of climb if H.P. available = 96, H.P. required = 62, weight of plane = 1,800 lb.

14. Volumetric efficiency of a gasoline engine.

$$\frac{\text{volume of charge}}{\text{piston displacement}} = \text{volumetric efficiency in per cent}$$

If an engine of 750 cu. in. piston displacement draws in a total of 645 cu. in. of fuel vapor and air mixture, its volumetric efficiency would be

$$\frac{645}{750} = 86.1\%$$

15. Find the volumetric efficiency of an engine of 645 cu. in. of piston displacement if it draws in a total of 542 cu. in. of fuel vapor and air mixture.

A formula for indicated horsepower is:

$$\frac{A \times \frac{S}{12} \times m.e.p. \times \frac{1}{2}\, r.p.m. \times N}{33{,}000}$$

A = area of top of piston

S = stroke in inches

$m.e.p.$ = mean effective pressure on the top of the piston in lb. per sq. in.

$r.p.m.$ = revolutions of the engine

(We use $\frac{r.p.m.}{2}$ in the formula because two revolutions of the crankshaft are required to produce one power impulse for each cylinder.)

N = number of cylinders

16. Find the indicated horsepower for each engine for which data are given:

Area of top of piston	*Stroke*	*m.e.p.*	*r.p.m.*	*N*
14	4	158	2540	2
24	5	178	2000	9
19.6	$5\frac{1}{2}$	142	2100	7
19.6	$5\frac{1}{2}$	141	2100	9

A formula for finding the tip speed of a propeller is:

$$T.S. = 3.1416 \times d \times r.p.s.$$

$$d = \text{diameter of propeller in ft.}$$

$$r.p.s. = \text{revolutions per sec.}$$

Example:

Find the tip speed of a propeller 7 ft. 9 in. in diameter if it turns at 1,200 r.p.m.

Solution:

$$1{,}200\ r.p.m. = 20 \text{ r.p.s.}$$

$$T.S. = 3.1416 \times 7\tfrac{3}{4} \times 20$$

$$T.S. = 487 \text{ ft. sec.}$$

1. The propellers of the Boeing Clippers have a diameter of 14 ft. 10 in. What is the tip speed at 2,400 engine r.p.m.? (The gear ratio in the clipper is 16/9, which means that for every 16 revolutions of the engine there are 9 revolutions of the propeller.)

2. Find the tip speed of the clipper propeller for 1,500 engine r.p.m.

3. The propeller of the Aeronca 65 is 73 in. in diameter. The propeller drive is direct, which means that for every engine revolution there will be one propeller revolution. Find the tip speed at 2,500 revolutions.

4. The Pratt and Whitney Wasp S3-H1-G has a drive ratio

of 0.667. The propeller diameter, in a plane which uses this engine, is 108 in. Find the tip speed at 2,200 r.p.m.

5. The Wright G 202 A has a 3/2 reduction gear. If the propeller diameter is 93 in. what is its tip speed at 2,300 engine r.p.m.?

6. Find the tip speed for a propeller of 105 in. diameter for an engine speed of 2,000 r.p.m. if the reduction gear ratio is 16/11.

7. If a reduction gear has a ratio of 0.5625 and a propeller is 85 in. in diameter, what is the tip speed at 2,200 engine r.p.m.?

8. Find the tip speed for a propeller 8 ft. in diameter if the reduction gear has a 19/6 ratio, for engine operation at 2,100 r.p.m.

The formula for freely falling bodies (see chapter on graphs) is $s = \frac{1}{2}gt^2$. This formula shows the relation between distances in feet and time in seconds and the constant g, which is called the acceleration of gravity. g is slightly more than 32 ft. per second for each second. A body falling from a position when it is not in vertical motion falls 32 ft. the first second, 64 ft. the second second, etc. Air resistance has an effect on the rate of fall of a bomb, but this effect will not be considered in the following problems.

Example:

A bomb dropped from a plane reaches its target in 5 sec. How high was the plane flying?

Solution:

$$t = 5$$

$$s = \frac{32}{2} \times 25$$

$$s = 400 \text{ ft.}$$

1. The bombardier released a bomb on a target at sea and observed that the bomb struck the target in $8\frac{1}{2}$ sec. after it was released. What was the altitude of the blimp at the time the bomb was dropped?

2. Change the subject of the formula $s = \frac{1}{2}gt^2$ so that you can find the value of t directly if s is known.

3. If t represents the time in seconds and s the distance fallen, find the time required for bombs to fall the following distances: 750 ft., 840 ft., 2,650 ft., and 14,260 ft.

4. How long will it take a bomb to fall from a plane flying at an altitude of 3,500 ft.?

5. If the bomber in problem 4 is flying at 225 ft. per second, how far does the plane travel between the time the bomb is dropped and the hit is scored? (Assume that the plane is in level flight.)

6. How many seconds are required for a bomb to reach the ground after being dropped from a plane if the plane is in level flight at an altitude of 2,750 ft. at the time the bomb is released?

7. If the bomber in problem 6 is flying at a speed of 265 m.p.h., how far does it travel between the time it is released and the time it hits?

8. The bombardier released a bomb while his plane was flying at 150 m.p.h.; $5\frac{3}{4}$ sec. later the bomb hit near its target. How far had the plane traveled during this time, and at what altitude was it flying?

To calculate the fuel load of an air-cooled engine in pounds the following formula is used:

$$\text{fuel load} = 0.55 \times 0.75 \times \text{B.H.P.}$$

0.75 represents 75% of the maximum brake horsepower.

0.55 lb. = specific fuel consumption per brake horsepower per hour.

1. Find the fuel load for an aircraft engine designed to develop 550 H.P.

2. For liquid-cooled engines the specific fuel consumption is figured at 0.50. Find the fuel load for a liquid-cooled engine designed for 400 H.P.

3. Find the difference in designed fuel loads for engines of 250 H.P. if one is to be air-cooled and the other liquid-cooled.

4. Find the fuel load for an air-cooled engine of 475 H.P.

5. A formula for calculating the oil load of an engine is:

$$\text{pounds of oil} = \frac{\text{pounds of fuel}}{6} \times \frac{1}{14} \times 7.5$$

From this formula find the weight of oil required for 1 lb. of fuel.

6. Making use of the answer in problem 5, find the weight of oil required in problems 1, 2, and 4.

Standard sea-level pressure is expressed as the amount of pressure required to support a column of mercury 29.92 in. high.

The standard temperature is 15° C.

An air-speed indicator gives the speed of a plane in relation to the surrounding air. It is necessary to observe the thermometer and barometer readings under flying conditions, and substitute these readings in the formula to find the true air speed.

$$\text{true air speed} = \text{indicated air speed}\sqrt{\frac{\text{actual temperature}}{\text{standard temperature}} \times \frac{\text{standard pressure}}{\text{actual pressure}}}$$

Expressed in symbols, this is:

$$S_1 = S\sqrt{\frac{C_1}{C} \times \frac{P}{P_1}}$$

Find the true air speed from the data here. *(Copy the table. Do not write in this book.)*

	Indicated Air Speed m.p.h.	*Actual Temperature Centigrade*	*Actual Pressure inches*	*True Air Speed*
1.	140	23°	28.6	
2.	125	25.6°	27.9	
3.	115	18.2°	29.0	
4.	131	17.3°	27.7	
5.	145	19.4°	28.1	

In bending metal for various aircraft parts allowance must be made for the contraction of the metal on the inside of the bend

and for expansion on the outside. If a piece of metal were bent so as to form a perfect circle, the formula for the bend allowance would be obtained as follows:

$$\text{circumference of inner circle} = 2\pi R.$$

The thickness of the metal is represented by T.

The length of the neutral line, or line located halfway between the inner and the outer circle $= 2\pi(R + \frac{1}{2}T)$

$$N = 2\pi R + \pi T$$

(The theoretical bend allowance for 360°.) The theoretical bend allowance for $1° = \dfrac{2\pi R + \pi T}{360}$

$$B.A. \text{ for } 1° = 0.01745R + 0.0087T$$

In practice, however, it has been found that the formula that actually works is $(0.01743R + 0.0078T) \times A$, where A is the angle of bend.

Find the bend allowance in each case from the data:

R	T	A
4″	$\frac{3}{8}$″	37°
10″	$\frac{5}{16}$″	52°
2″	$\frac{1}{2}$″	3°
1′ 2″	$\frac{1}{8}$″	25°
3″	$\frac{3}{16}$″	75°

A formula for changing Fahrenheit to Centigrade temperature is:

$$C = \frac{5}{9}(F - 32)$$

Change the subject of the formula so that F will be in terms of C.

Complete the following table. *(Do not write in this book.)*

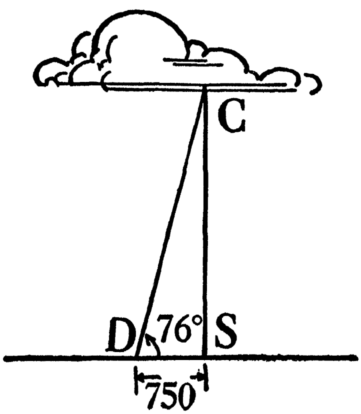
	Centigrade	*Fahrenheit*
1.	10°	
2.		80°
3.	15°	
4.		60°
5.	57°	

CHAPTER 18

TRIGONOMETRY

1. A blimp while on patrol duty observes that the angle of depression to the base of a lighthouse is 32°. If the blimp is stationary at an altitude of 1,460 ft., what is the distance from a point just beneath the blimp to the lighthouse?

2. A searchlight which is 750 ft. from a point directly under a cloud is inclined at an angle of 76° when its beam hits the cloud. What is the ceiling (height of cloud) over the airport?



3. The angle of elevation from the position of an observer to a plane is 32°. If the plane is known to be flying at a height of 3,200 ft., what is the distance from the observer to the plane?

4. For 175 mi. a ship has been holding its course 19° east of north. How far north is the ship? how far east?

5. An airplane is headed east at a speed of 115 m.p.h. There is a north wind of 32 m.p.h. velocity. What is the true velocity of the plane? Use graph paper.

6. An airplane is headed north at a speed of 120 m.p.h. At the same time there is a west wind of 26 m.p.h. velocity. Find the actual velocity of the plane.

7. Find the ground speed of a plane with an air speed of 95 m.p.h. climbing at an angle of 11°. Find the ground speed if the angle of climb is 5° 30′ and the air speed is 110 m.p.h.

8. If the ground speed is 95 m.p.h. and the angle of climb is 7°, what is the air speed?

9. The ground speed of a plane is 110 m.p.h. and the angle of climb is 6° 30′. What is the air speed?

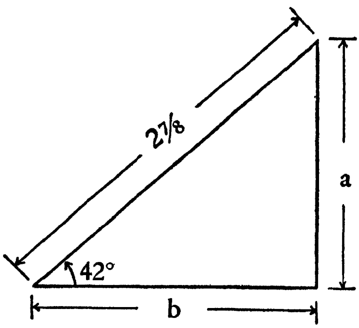
10. For 80 mi. a plane has been traveling 37° west of north. How far north and how far west from the starting point has it traveled?

11. Lay out an angle if the slope is 0.372.

In some work a line slanting from the horizontal is located by giving the slope of the line rather than the angle the line makes with the horizontal. (The *slope* is the tangent of the angle.) If the slope is given as 0.7245, this means that 1 unit is measured on the horizontal and 0.7245 on the vertical.

12. Find angle in degrees and minutes if the slope is 0.6250.

13. Find angle in degrees and minutes if the slope is $\frac{7}{8}$.



14. The angle of depression from the lookout tower at a coast-guard station to the pontoon of a flying boat in the bay was 13°. If the observer was 38 ft. above sea level, how far out was the boat from the base of the tower?

15. If the wind velocity is 25 m.p.h. from 90° and the air speed is 115 m.p.h. due south, what are the angle of drift and the ground speed?

16. Find a and b from data given in the diagram above.

Equation to use in solving any hole-spacing problem:

Line between 2 consecutive holes $= 2r \times \sin \dfrac{180°}{n}$

$r =$ radius of circle on which holes are to be located

$n =$ number of holes

17. Using the formula, find the distance between holes (D) where $r = 16$ and $n = 25$.

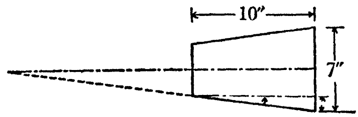
18. Find the distance between two consecutive holes if the holes, 6 in number, are to be equally spaced. The radius of the circle is 8 in.

19. A metal part for a plane is to have holes bored in such a way that their centers will lie on a circle of 8-in. radius. There

are to be 12 holes. Find the distance between the centers of any two successive holes.

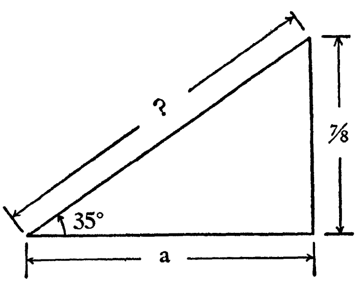
20. A submarine known to be cruising on the surface at 16 knots is intercepted by a navy blimp traveling at 55 knots. If the blimp required 3 hr. 45 min. to overtake the submarine, how far was the submarine from the starting point of the blimp? If the blimp sailed a constant course of 135° in overtaking the submarine, how far due east was the point of interception from the starting point of the blimp?

21. Find the angle of taper and the small diameter if the taper is 1 in. in 12 in.



22. Find the value of a in the template layout diagrammed below.

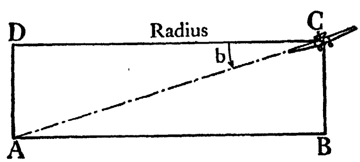
23. For 1 hr. a plane has been flying a true course of 6°. If its average ground speed is 170 m.p.h. and there is no wind, what is its distance north of the starting point? east of the starting point?



24. If the glide radius of a model plane is known to be 3,700 ft. and the altitude of glide is 420 ft., what is the angle of glide?

To find the angle of bank b if the plane is flying a circle of 2,000 ft. radius at the pivotal altitude of 609 ft.

$$\text{Tan } \angle B = \frac{609}{2000}$$

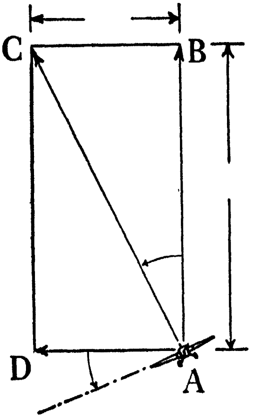


25. Find the angle of bank if the pivotal altitude is 950 ft. and the radius is 3,250 ft.

26. Find the angle of bank if the pivotal altitude is 700 ft. and the radius is 1,764 ft.

27. Solve the following from the data given. A plane weighs 1,750 lb. Centripetal force is 850. Find the angle of bank. To

find the angle of bank needed if the weight of the plane and the centripetal force are known, divide the value of CB (in the diagram) by the value of BA. CB represents the centripetal force and BA the weight of the plane.



28. A plane is flying a circle at a 36° bank. If the plane weighs 1,350 lb., what centripetal force is being exerted?

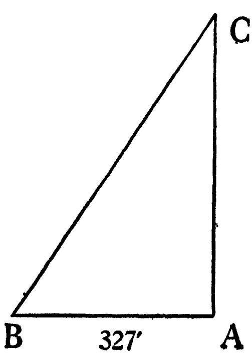
29. If a plane can climb at 15°, what vertical distance can it climb in 17 min. at 90 m.p.h.? Make a line graph that will indicate the vertical distance of the plane for different times if the rate remains constant at 90 m.p.h. From your graph read the vertical distance 19 min. after leaving the ground.

30. The navigator of the blimp while on patrol duty observes that the angle of depression from the control cabin to the base of a lighthouse is 25°. If the blimp is stationary at an altitude of 1,650 ft., what is the distance from a point just beneath the blimp in the water to the lighthouse?

31. What angle of glide would be necessary for a plane to glide 1 mi. from a height of 750 ft.? from a height of 900 ft.? from a height of 1,200 ft.?

32. From position A a balloon is observed to rise straight into the air. The distance BA is known, and the observer at B notes the following angles made by the line of sight with the horizontal BA. What is the height of the balloon for each of the angles recorded? *(Do not write in this book.)*

Angle	*AC*
47°	
52°	
75°	
84°	

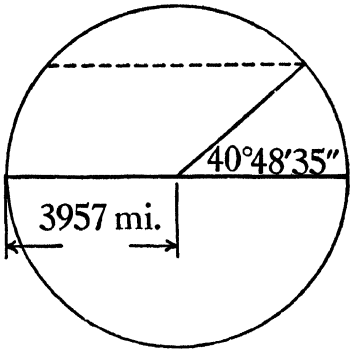


33. At 108 knots how long will it take a clipper to gain an altitude of 1,000 ft. if the angle of climb is 3° and no allowance need be made for wind?

34. A special service destroyer is detailed to tow and tend a captive balloon. While on patrol duty it is observed that the towing cable makes an angle of 65° with the deck of the ship. If 1,562 ft. of cable have been let out by the winch, what is the height of the balloon? If 1,750 ft. had been released, what would be the height if the angle remained the same?

35. The Boeing Stratoliner has a rate of climb of 1,200 ft. per minute with 4 engines, of 600 ft. per minute with 3 engines, and of 113 ft. per minute with 2 engines. Find the horizontal distance for each rate of climb at 80 m.p.h.

36. Find the number of miles equivalent to each degree of longitude on parallel of latitude east or west of Duluth, Minnesota, 46° 47′ 21″.



The figure suggests a method for finding the radius of a circle of latitude through any point on the earth's surface. The latitude shown is that of New York City.

Formula for finding the great-circle distance between two points on the earth's surface is:

$$\cos X = (\cos A \times \cos B \times \cos D) + (\sin A \sin B)$$

A = latitude of one place

B = latitude of the other place

D = difference in longitude

X = number of degrees along the great circle passing through the two points

$1^\bullet = 69.1$

1. Find the great-circle distance between Ogden, Utah, lat. 41° 13′ N., long. 112° W., and Oklahoma City, Oklahoma, lat. 35° 29′ N., long. 97° 30′ W.

2. Find the distance between Hartford, Connecticut, lat. 41° 46′ N., long. 72° 41′ W., and Halifax, lat. 44° 40′ N., long. 63° 35′ W.

3. Find the great-circle distance from New York to Bermuda to Lisbon.

	Latitude	*Longitude*
New York	40° 48′ 35″ N.	73° 57′ 30″ W.
Bermuda	32° 19′ 22″ N.	64° 49′ 34″ W.
Lisbon	38° 42′ 31″ N.	9° 11′ 10″ W.

4. Find the great-circle distance between Des Moines, lat. 41° 35′ 40″ N., long. 75° 31′ 25″ W., and Tokyo, lat. 35° 39′ 17″ N., long. 139° 44′ 33″ E.

5. Find the great-circle distance between New York, lat. 40° 48′ 35″ N., long. 73° 57′ 30″ W., and Tokyo, lat. 35° 39′ 17″ N., long. 139° 44′ 33″ E.

6. Find the great-circle distance between San Francisco, lat. 37° 47′ 28″ N., long. 122° 25′ 43″ W., and Tokyo, lat. 35° 39′ 17″ N., long. 139° 44′ 33″ E.

7. Find the great-circle distance from your town to Bremen, Germany, lat. 53° 4′ 40″ N., long. 8° 48′ 40″ E.

8. Find the great-circle distance between St. Johns, Newfoundland, lat. 47° 34′ 2″ N., long. 52° 40′ 54″ W., and Bristol, England, lat. 51° 27′ 24″ N., long. 2° 34′ 44″ W.

9. Find the great-circle distance between Moscow, lat 55° 45′ 20″ N., long. 37° 34′ 15″ E., and Liverpool, lat. 53° 24′ 05″ N., long. 3° 4′ 20″ W.

10. If the wind velocity is 20 m.p.h. from 270° and the air speed is 120 m.p.h. course due north, what is the angle of drift?

11. Two cities are located at lat. 37° 52′ N. One is long. 122° 15′ 42″ W., the other 76° 30′ W. Find the distance measured by the line of latitude between the two points. Find the great-circle distance between the points and the difference between the two distances.

12. Find the great-circle distance between New York and Berlin; between Chicago and Berlin; between San Francisco and Berlin.

	Latitude	*Longitude*
New York	40° 48′ 35″	73° 57′ 30″
Chicago	41° 50′ 1″	87° 36′ 43″
San Francisco	37° 47′ 28″	122° 25′ 43″
Berlin	52° 31′ 31″	13° 21′ 51″

Example I:

A plane makes its best angle of climb in still air at a speed of 70 m.p.h. Its rate of climb is 800 ft. per minute. In taking off into a 15 m.p.h. wind, it leaves the ground at a distance 500 ft. from an obstruction 50 ft. high. Will it clear the obstruction?

Solution:

$$70 \text{ m.p.h.} = 6{,}150 \text{ ft. per min.}$$

$$15 \text{ m.p.h.} = 1{,}320 \text{ ft. per min.}$$

$$\text{horizontal speed through air} = \sqrt{6150^2 - 800^2}$$

$$= 6{,}097 \text{ ft. per min.}$$

$$\text{horizontal speed over ground} = 6{,}097 \text{ ft.} - 1{,}320 \text{ ft.}$$

$$= 4{,}777 \text{ ft. per min.}$$

Traveling 4,777 ft. horizontally, the plane rises 800 ft. vertically; then traveling 500 ft. horizontally the plane will rise $\frac{500 \times 800}{4777}$ $= 83.9$ ft. It will clear the obstruction by 33.9 ft.

Example II:

A plane has a rate of climb of 450 ft. per minute when its air speed is 40 m.p.h. What is its true angle of climb into a 14 m.p.h. wind?

Solution:

$$40 \text{ m.p.h.} = 3{,}520 \text{ ft. per min.}$$

$$14 \text{ m.p.h.} = 1{,}232 \text{ ft. per min.}$$

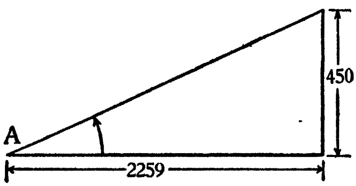
$$\text{horizontal speed through air} = \sqrt{3520^2 - 450''}$$

$$= \sqrt{(3970)(3070)}$$

$$= 3491 \text{ ft. per minute}$$

$$\text{horizontal speed over ground} = 3491 - 1232$$

$$= 2259 \text{ ft. per min.}$$



$$\tan A = \frac{450}{2259}$$

$$\log \tan A = 9.2993 - 10$$

$$A = 50° \ 37'$$

1. A plane makes its best angle of climb in still air at 55 m.p.h., the rate of climb being 700 ft. per minute. At what horizontal distance from the point of take-off will the plane have an altitude of 900 ft. in a straight take-off in a 20 m.p.h. wind?

2. A plane makes its best angle of climb in still air at 60 m.p.h., its rate of climb being 720 ft. per minute. It climbs into a 15 m.p.h. wind. What will its altitude be 600 ft. from the point of take-off? What is the angle of climb? See Example I.

3. A plane makes its best angle of climb at 50 m.p.h. Its rate of climb is 600 ft. per minute. What will its altitude be at a point on the ground 500 ft. from the start?

Best rates of climb in still air, wind rates, and air speeds are given in the table. Find the angle of climb. See Example II. *(Do not write in this book.)*

	Air Speed m.p.h.	*Rate of Climb ft. per min.*	*Rate of Wind m.p.h.*	*Angle of Climb*
Into wind	55	720	15	
" "	62	650	12	
" "	65	700	20	
" "	58	450	22	
" "	72	800	14	
" "	75	900	20	
" "	60	700	15	
" "	57	620	16	
" "	59	560	18	
" "	66	710	15	

CHAPTER 19

NAVIGATION

Effect of Wind on Air Navigation

WE SHALL now consider a list of definitions that are used in connection with problems of air navigation. In solving the problems in this section you will frequently need to refer to these definitions. It is recommended that you study them carefully before solving the problems.

Ground speed: The actual speed of the plane over the surface of the earth.

Drift angle: The angle between the direction the plane is heading and the track, or path of the plane over the earth.

Drift correction angle: This is the angle to be added to or subtracted from the course, or direction in which the pilot intends to go, to get the direction the plane must be headed. In the case of a right drift the correction angle is to be subtracted from the course angle, and in the case of a left drift it is to be added.

Course: This is the *direction* over the surface of the earth, expressed as an angle, that the plane is to be flown. This angle is measured clockwise from north, as are all angles used in this work.

Course made good: The true direction the plane heads after corrections have been made.

Track: Actual path of an aircraft over the surface of the earth. The track is the path that has been flown. The true course is the path the pilot intends to fly.

Heading: The angle made by the longitudinal axis of the plane and true north. It is the course with the drift correction applied.

Wind direction and force: Wind is described by the direction from which it blows. The force of the wind is expressed as the speed in knots or miles per hour.

Velocity: The rate of change of position in any given direction. It involves both speed and direction.

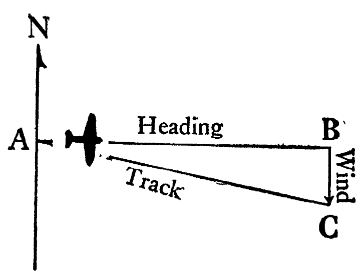
Line: A straight line is used to represent a velocity. The position of the line represents direction and the length of the line represents speed.

No wind: The air speed will be the same as the ground speed when there is no wind. The heading and course will also be the same under no-wind conditions. This condition is seldom encountered, so the wind must usually be taken into account. The change in the rate of travel and the change in direction may be solved by the same vector diagram. There are two cases which do not need a diagram, and these are the rare cases when the airplane course is exactly with the wind or against the wind.

Example I. An airplane, air speed 140 m.p.h., is flown directly into a 20 m.p.h. head wind. The ground speed then equals 120 m.p.h., and the heading and course are the same.

Example II. An airplane, air speed 160 m.p.h., is flown directly down wind (with the wind). The ground speed then equals the air speed plus the wind velocity. If the wind velocity is 20 m.p.h., the ground speed is 180 m.p.h., and the course is the same as the heading.

Vector diagrams: For purposes of this work a vector is a line segment having a definite direction. A velocity may be represented in a vector diagram by a straight line. The line is drawn in the same direction as the motion, and the length of the line represents the rate of motion.



Wind diagram: In the wind-vector diagram the heading and air speed are drawn as one component and the wind direction and velocity as the second component. The resultant then indicates the course and the ground speed.

General directions and suggestions for solving problems:

Neatness counts.

Draw lines with a sharp-pointed hard lead pencil.

Label all lines as soon as drawn.

Read the problem with great care so there will be no confusion as to what is required.

It is helpful to make a rough sketch before starting the detailed diagram.

Plan the spacing of the diagram carefully.

Remember that wind always blows the plane from the heading to the course.

Heading and air speed are always on the same line.

There are six elements to consider in working with problems involving wind direction and velocity. They are course, ground speed, air speed, track, wind direction, and wind velocity.

Most of the problems in elementary navigation are concerned with aircraft which have two velocities at the same time. Suppose that an aircraft is flying directly east at 100 m.p.h. in a wind that is blowing 20 m.p.h. from the north. In an hour the aircraft will have flown 100 mi. due east from A to B but the wind will have blown it 20 mi. due south to C and the plane will have flown straight from A to C. If the triangle ABC is drawn to scale so that AB and AC are the true vector velocities of aircraft and wind, the triangle ABC is called the triangle of velocities. AC is the resultant of AB and BC. AB and BC are called the component velocities.

Figure 1 (page 142) illustrates what happens if a plane is heading 35° from A and a wind is blowing from 270° at a velocity of 32 m.p.h. If the air speed of the plane is 100 m.p.h., at the end of 1 hr. flying the pilot will find he is at position B'. The track will be $47\frac{1}{2}°$. The drift angle is found to be $12\frac{1}{2}°$. The ground speed of the plane is slightly over 121 m.p.h.

A convenient way to solve this problem is to use graph paper ruled ten divisions to the inch. Decide on a scale. In this case we have chosen one small division to represent 5 mi. The heading is determined by measuring $\angle NAD = 35°$ with a protractor. With A as a center and with a radius representing 100 mi., draw an arc cutting AD at B. Through point B draw a line parallel to AX and with A as a center, using a radius to represent 32 m.p.h., draw an arc cutting BX' at B'. Now draw AB'. $\angle BAB'$ is the drift angle, or the angle between the course and the track. The length of the track is AB'. It is found to be 121 units long. It also is the ground speed (121 m.p.h.). This is an illustration of a vector.

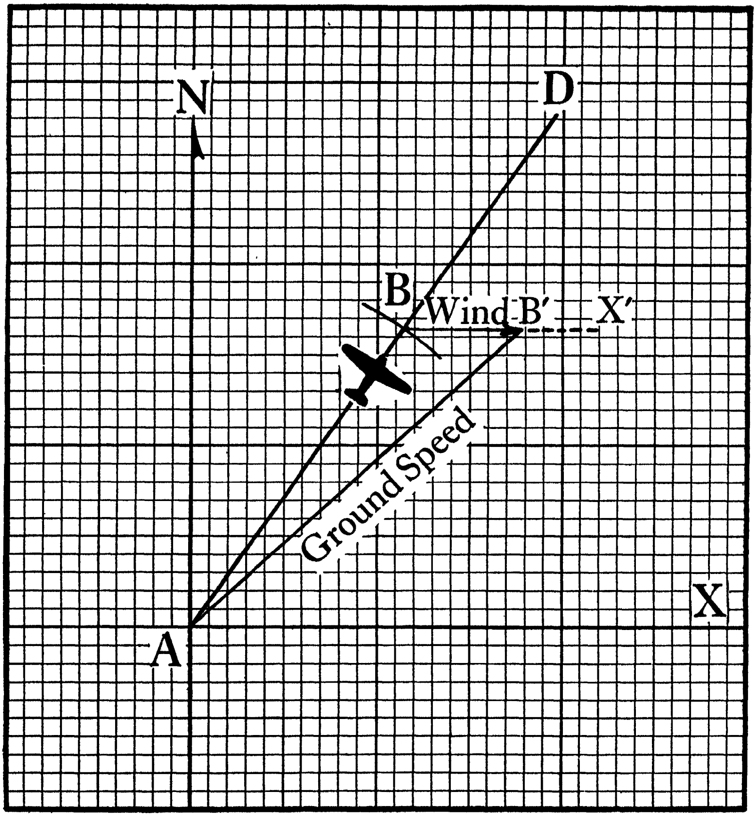


Fig. 1

Solution by Trigonometry

After you have solved the problem by scale drawing and have found the $\angle BAB'$ with a protractor, it is a simple matter to solve for AB' by using the law of sines. This solution would also serve as a partial check on your work. The solution is as follows:

$$AB' = \frac{32 \sin 55°}{\sin 12\tfrac{1}{2}°}$$

$$\log 32 = 1.5051$$

$$\log \sin 55° = 9.9132 - 10$$

$$\text{colog } \sin 12\tfrac{1}{2}^\circ = .6647$$
$$\log AB' = 12.0832 - 10$$
$$AB' = 121.+$$

It is possible also to use the law of cosines to check the work, and this time we start only with the given values.

$$(AB')^2 = (AB)^2 + (BB')^2 - 2(AB)(BB')(-\cos 55^\circ)$$
$$(AB')^2 = 10{,}000 + 1024 + 3671$$
$$(AB')^2 = 14{,}695$$
$$AB' = 121.+$$

Having found AB', we can make use of the law of sines to get the drift angle as follows:

$$\sin \angle BAB' = \frac{32 \sin 55^\circ}{121}.$$
$$\log 32 = 1.5051$$
$$\log \sin 55^\circ = 9.9132 - 10$$
$$\text{colog } 121 = 7.9172 - 10$$
$$\log \sin \angle BAB' = 19.3357 - 20$$
$$\angle BAB' = 12^\circ\ 30'$$

Use graph paper ten divisions to an inch. Make all constructions and measurements with great care.

Using the method of Example I find the track, the ground speed, and the angle of drift in each case given here:

	Course	*Air Speed m.p.h.*	WIND *From*	WIND *Velocity m.p.h.*
1.	135°	120	110°	30
2.	170°	110	310°	20
3.	300°	105	330°	18
4.	250°	95	165°	15
5.	42°	125	300°	40
6.	72°	200	110°	17
7.	180°	150	165°	32
8.	150°	147	310°	10
9.	0°	130	350°	30
10.	180°	113	176°	40

(Trigonometry students: Using the law of sines, check each ground speed as in the given example.)

In the problems just considered we have found the track and ground speed resulting from flying a given course. You can see that after flying for an hour in each case the pilot will be off his course. The second type of problem is to determine the heading and ground speed when the wind velocity and direction and the air speed of the plane are known.

A pilot wants to fly from A to B, directly north of A. His air speed is 110 m.p.h. The wind is from 300° with a velocity of 25 m.p.h.

Lay off a north line from A.

Using the scale as in the sample problem for the first type, lay off the wind vector. From point W of the wind vector, as a center, using a radius representing an air speed of 110 m.p.h.,

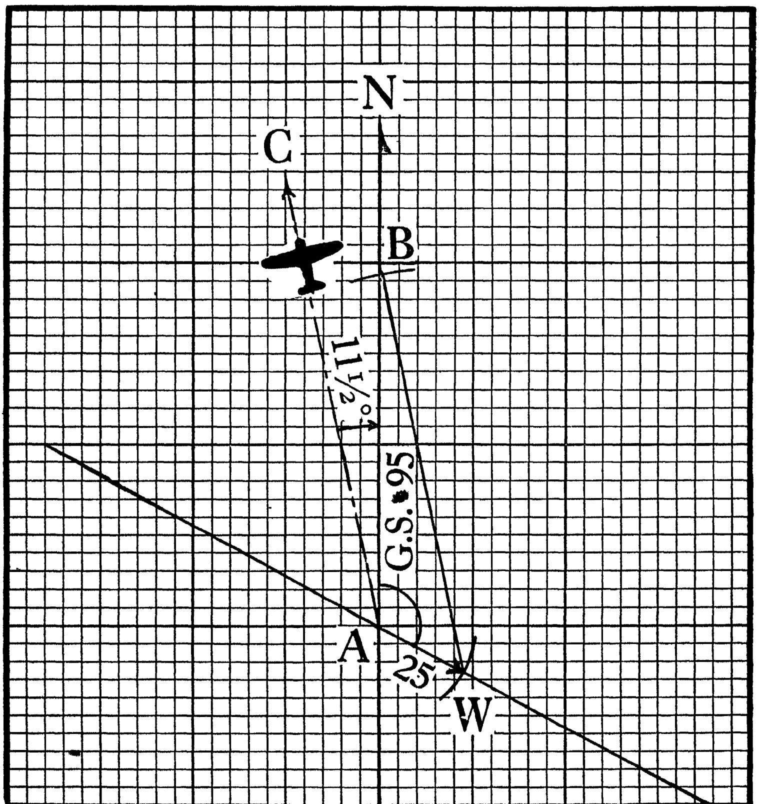


Fig. 2

draw an arc cutting the north line at B. AB is the ground speed. CA is the heading the pilot must fly in order to arrive at B.

The heading is $11\frac{1}{2}°$ to the left of north, or $348\frac{1}{2}°$.

The CAB is sometimes called the *crab angle.* It is the angle measured to the left of the course in this case. It is the drift correction angle.

$$\angle CAB = 11\tfrac{1}{2}°$$

$$\text{ground speed} = 95 \text{ m.p.h.}$$

(Check by trigonometry)

Find $\angle B$. $\quad \sin B = \dfrac{25 \sin 60°}{110}$

$$\begin{aligned} \log 25 &= 1.3937 \\ \log \sin 60° &= 9.9375 - 10 \\ \text{colog } 110 &= 7.9586 - 10 \\ \hline \log \sin B &= 19.2940 - 20 \\ B &= 11\tfrac{1}{2}° \quad \text{(to the nearest half-degree)} \end{aligned}$$

Find GS. $\quad GS = \dfrac{110 \sin 48\frac{1}{2}°}{\sin 60°}$

$$\begin{aligned} \log 110 &= 2.0414 \\ \log \sin 48\tfrac{1}{2}° &= 9.8744 - 10 \\ \text{colog } \sin 60° &= .0625 \\ \hline \log GS &= 11.9783 - 10 \\ GS &= 95 \text{ m.p.h.} \end{aligned}$$

Given the air speed, wind data, and course to fly, find the heading and ground speed in each case that follows. Use the method outlined for Example II.

			WIND	
	Course	*Air Speed m.p.h.*	*From*	*Velocity m.p.h.*
1.	165°	115	270°	18
2.	275°	125	35°	30
3.	35°	140	145°	10
4.	185°	110	285°	16
5.	310°	95	85°	25
6.	360°	100	165°	20

	Course	Air Speed m.p.h.	WIND From	WIND Velocity m.p.h.
7.	225°	130	95°	8
8.	90°	122	280°	40
9.	170°	112	300°	15
10.	10°	200	80°	50

(Trigonometry students: Find the ground speed and the drift correction angle by trigonometry.)

SOLVING FOR WIND DIRECTION AND VELOCITY

If we know the heading, air speed, course flown, and ground speed, it is easy to determine the wind vector (direction and velocity of the wind).

Figure 3 shows A plane heading toward *B* with an air speed of 125 m.p.h. *AB′* represents the course made good, 100 m.p.h. and 115°. Find the wind direction and velocity. Remember that the wind is from the heading to the course. Draw *BB′*. At *B* draw a north line and measure $\angle NBC$. Measure *BB′*. This is the wind velocity. What is its length?

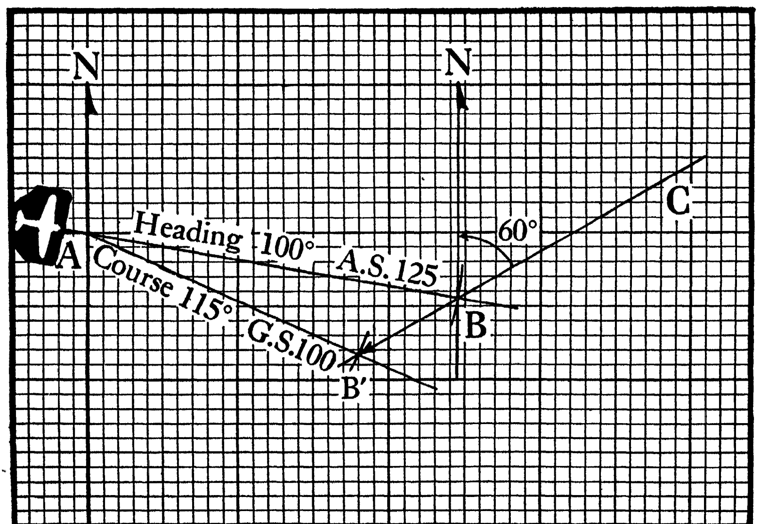


Fig. 3

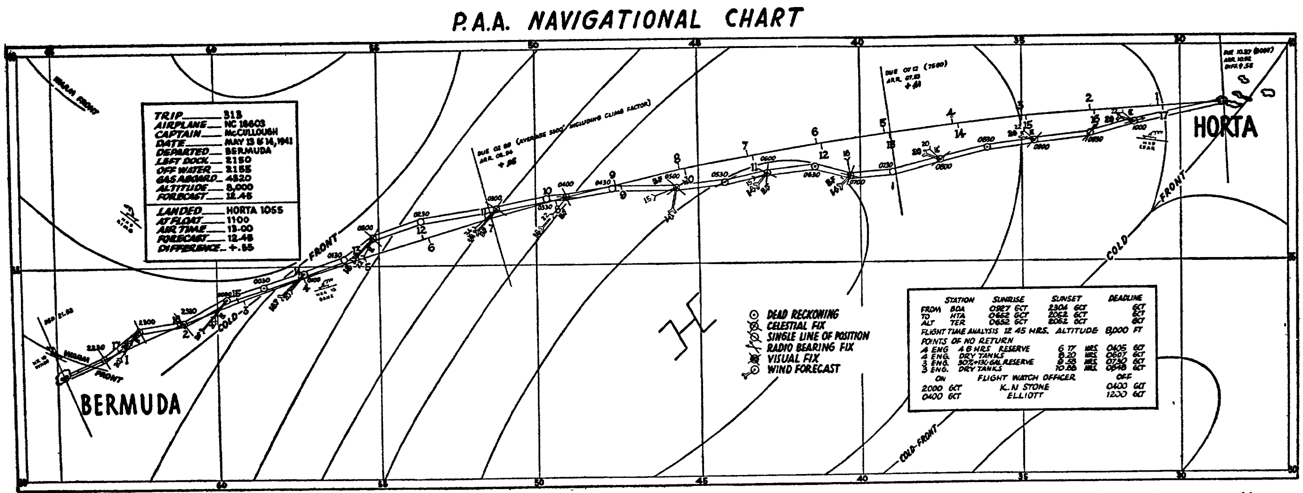
$$\angle NAC = 82\tfrac{1}{2}^\circ$$
$$BB' = 30.6$$

(Check by trigonometry.)

$$\angle A = 15^\circ$$
$$(BB')^2 = 125^2 + 110^2 - 2(125\cdot 110) \cos 15^\circ$$
$$(BB')^2 = 15626 + 12100 - 26562$$
$$(BB')^2 = 938$$
$$BB' = 30.6$$

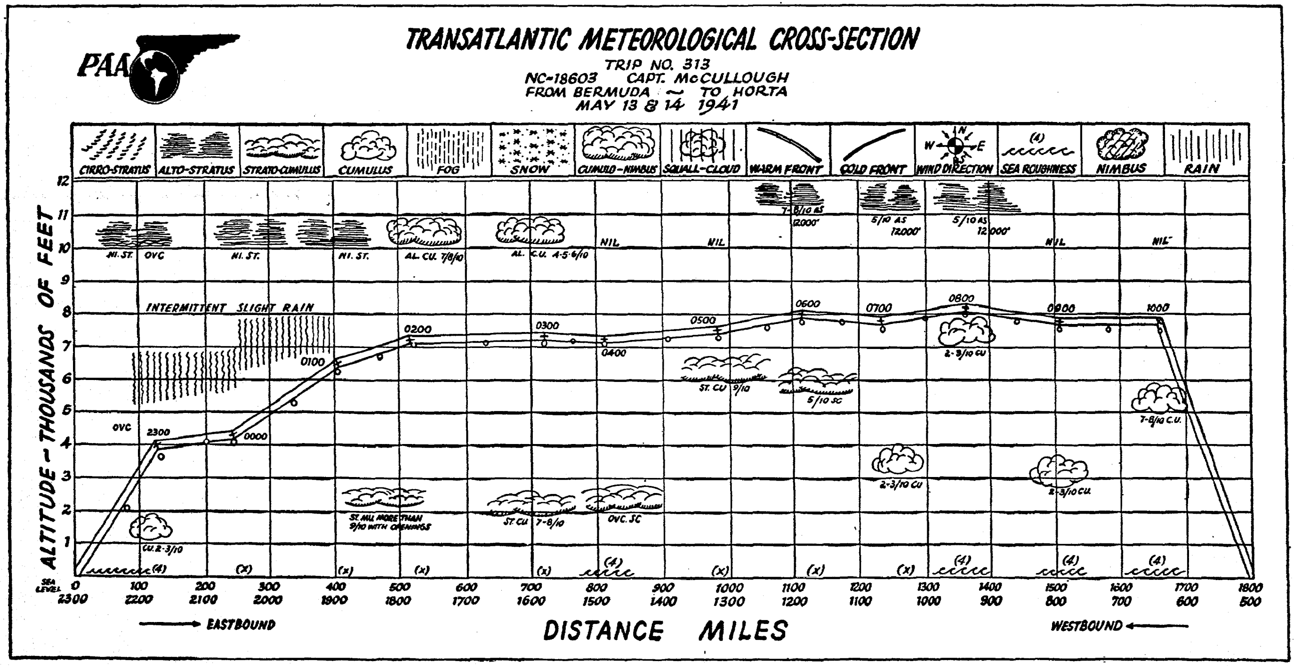
Complete the following table. *(Do not write in this book.)*

				WIND	
Course	*Heading*	*Air Speed*	*Ground Speed*	*Direction From*	*Velocity*
		m.p.h.	*m.p.h.*		
125°	117°	130	120		
300°	320°	115	118		
110°	75°	120	110		
330°	340°	150	160		
180°	190°	100	105		
290°	280°	125	135		
350°	360°	95	90		
90°	100°	170	165		
135°	125°	110	115		
0°	15°	160	150		



Courtesy, Pan American Airways

Placed in the isobar lines of dominant weather, the actual track of the aircraft indicates the course flown in avoidance of weather areas or to take advantage of helping winds.



Courtesy, *Pan American Airways*

This forecast is supplementary to the basic weather map and the upper air map from which all flight forecasts are made. It provides the captain with a visual description of conditions forecast for his crossing.

CHAPTER 20

RADIUS OF ACTION

THE radius of action of an airplane is the distance it may fly out on a certain course and have enough fuel for the flight back to the starting point or to some other point determined in advance.

The simplest type of radius-of-action problem is one in which the plane flies directly to a point and returns to its starting point under the condition of no wind. If a plane is capable of flying 3 hr. at 100 m.p.h. and still has a reserve of fuel as a margin of safety, it could fly 150 mi. in any direction from the starting point and return to that point.

As wind effect must usually be considered, it is necessary in most cases to find the heading out, the heading back, and the time to turn. The distance out depends on the fuel capacity of the plane, the most efficient air speed, fuel and oil consumption, the altitude, and the wind effect.

FORMULA I

A formula for computing radius of action returning to the same base is:

$$R = \frac{abt}{a + b}$$

Proof of the radius-of-action formula.

Perhaps the easiest way to think of the radius-of-action problem for return to the point from which the plane started, when the wind is blowing, is to take a simple problem and solve it by algebra.

That is, a plane has an available fuel supply for 4 hr. flying. The pilot calculates his ground speed out at 110 m.p.h., and his ground speed back at 95 m.p.h. In 4 hr. how far, on a fixed course, can he fly and return to the airport from which he started?

Solution:

Let $R =$ distance out (radius of action)

$\frac{R}{110} =$ time required going

$\frac{R}{95} =$ time returning

$4 =$ hours of flying time available

$$\frac{R}{110} + \frac{R}{95} = 4$$
$$95R + 110R = 41{,}800$$
$$205R = 41{,}800$$
$$R = 200.4 \text{ mi.}$$

Now in general the ground speed going is a m.p.h. The returning ground speed is b m.p.h.; t represents the number of hours available.

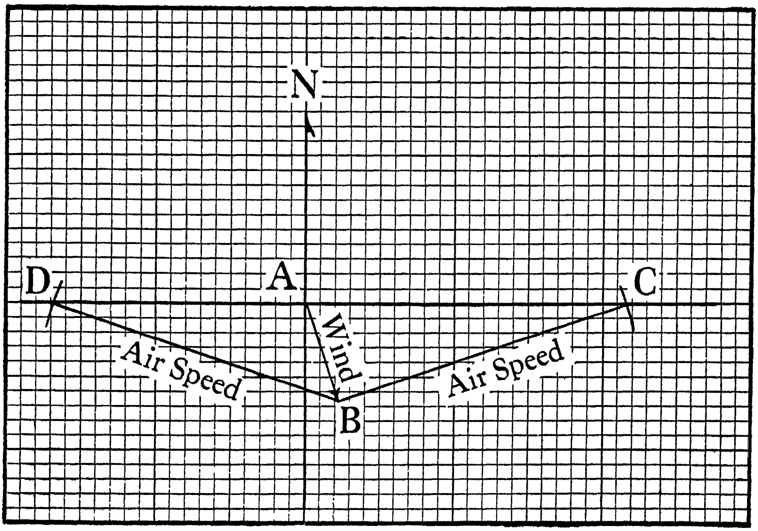


Fig. 1

A reserve of 25 per cent of the total fuel hours is usually held for emergencies; t, then, equals the total fuel hours minus 25 per cent of the total fuel hours.

Figure 1 is used to determine the heading out by the direction

of line BC, and the ground speed out by the length of line AC. DB represents the air speed back and the heading, while DA represents the ground speed back. This formula applies only to cases where the plane returns to the same base from which it started.

Problem:

If the ground speed out is 115 m.p.h., the ground speed back 110 m.p.h., and the total fuel hours for the plane is 6, find the radius of action.

Solution:

Substituting in the formula:

$$R = \frac{110 \times 115 \times 4.5^*}{110 + 115}$$

$$R = 253 \text{ mi.}$$

$$t^* = 6 - .25(6)$$

$$t = 4.5$$

Find the radius of action, as in the sample problem, for each of the cases given here.

	a *m.p.h.*	*b* *m.p.h.*	*Total Fuel hours*	*R*
1.	160	150	6	
2.	200	180	3	
3.	110	120	5	
4.	95	110	4	
5.	185	175	7	
6.	125	110	2	
7.	250	240	4	
8.	75	85	3	
9.	170	165	4	
10.	117	114	5	

If a pilot knows the air speed, the heading required to fly a course, the wind direction and velocity, he can compute the ground speed out. By completing the diagram, as in Figure 1, he can find the ground speed back. If his available fuel time is known, he can find the radius of action.

Construct a diagram to determine the ground speed out and the ground speed back, and substitute the values found in

Formula I to get R in each case. Note that t is the *available* fuel time.

Air Speed Out m.p.h.	*Heading*	*Wind Velocity m.p.h.*	*Wind Direction*	*Ground Speed Out*	*Ground Speed Back*	t	R
110	90°	20	30°			4	
125	345°	30	75°			5	
95	270°	10	250°			3	
117	200°	15	175°			$4\frac{1}{2}$	
115	280°	25	190°			$3\frac{3}{4}$	

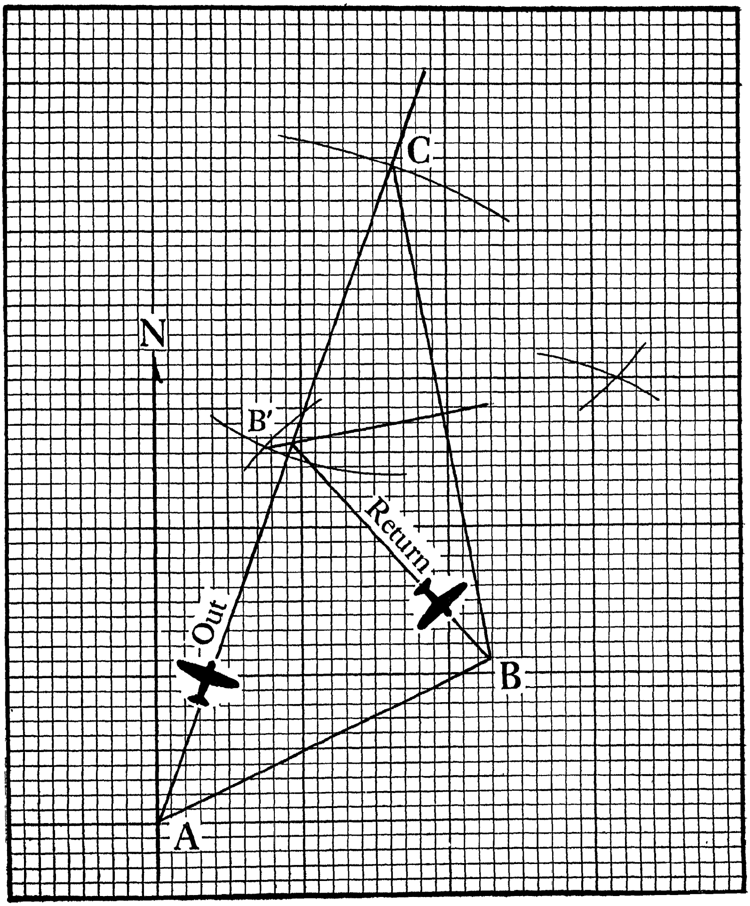


Fig. 2

A type of problem in which no wind is involved but in which a plane is to return to a second base, is solved as follows:

(See Figure 2). A plane sets out from A *with an available fuel supply for 4 hr. flying. Its course is 20° at 120 m.p.h. At what point must it turn in order to arrive at* B *at the end of 4 hr. flying?*

Draw AB. Lay off AC to represent 4 hr. flying at 120 m.p.h. on the starting course. Draw CB. Construct the perpendicular bisector of CB. At point B', where this line cuts AC, you have located the point of turning. $CB' = B\ B$. (Any point in the perpendicular bisector of a line is equidistant from the ends of the line.)

$$AB' + B'B = AB' + B'C \quad \text{(addition of equals)}$$

The course to fly is 20° as far as B', and $B'B$ from the turning point.

By using graph paper, plotting the starting course and drawing the lines to scale, determine the course $B'B$, and the length of AB'. (B is 252 mi. from A at 65°.)

Find the point of turning in each case given here, where a plane is to be flown from one point and return to another. (No wind.)

Air Speed Out m.p.h.	*Available Flying Hours*	*Course*	*At*	*B Located Miles from A*
115	4	35°	75°	300
120	$2\frac{1}{2}$	340°	375°	165
95	3	180°	170°	100
165	$\frac{5}{6}$	270°	285°	75
112	5	72°	90°	400
125	3	345°	270°	125
150	5	75°	90°	400
136	$3\frac{1}{2}$	275°	300°	150
127	$2\frac{3}{4}$	300°	200°	50
140	3	177°	160°	210

Radius-of-action problem when the wind is blowing and the plane is to return to a different base. (See Figure 3.)

A plane is required to leave A, *scout as far as possible on a course of 25° and return to base* B *at the end of 4 hr. The air speed is to be 100 m.p.h. for the entire trip. The wind is 30 m.p.h. from 90°.*

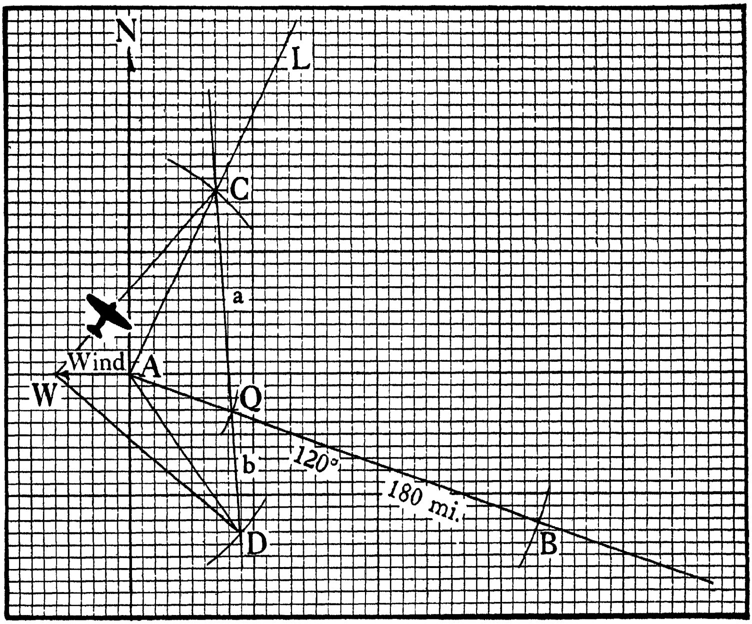


Fig. 3

Draw AL to represent the course out, 25°.

AB, the distance between the bases, is 180 mi. The bearing of B from A is 120°.

On AB find a point Q so that $AQ = 45$ mi. The plane in this problem has 4 hr. of flying time available, and AQ is the distance AB divided by 4.

Draw $AW = 30$ mi. from 90°. This is the wind vector.

From W draw an arc cutting AL at C, so that $WC = 100$ m.p.h.

Draw CQ and extend this line well below Q.

With W as a center and a radius representing 100 m.p.h., draw an arc cutting CQ extended at D.

Draw AD and WD. In triangle ACW, AC is the course and ground speed, and the ground distance traveled in 1 hr. WC

is the heading and air distance traveled in 1 hr. AW is the direction and velocity of the wind. The line AB represents the total distance from point A to the new landing position. The line WD represents the heading angle for the return trip and the line AD represents the direction of the course back.

In this problem B might be a permanent landing base or a carrier which will arrive at B at the correct time. If we assume that B is a carrier moving at a uniform rate of speed from A toward B, the point Q represents the position of the carrier 1 hr. after the plane took off from it. AQ represents a 1-hr. unit, the distance the carrier travels in 1 hr.

If the time out is 1 hr., the airplane then would be at point C. To intercept the carrier from this point, the pilot would take the heading represented by the direction WD.

He would make good a course from C represented by the direction AD, and intercept the carrier at a point between Q and B. The return trip would take more than 1 hr. As long as the wind velocity and all speeds and all directions remained the same, the airplane could be turned at any time from its outward course, and would intercept the carrier by following the heading back.

In Figure 3 the length of CQ represents the rate of departure (per hour) from the carrier. When the airplane is at C 1 hr. after the take-off, the carrier is at Q. The length of QD represents the rate of return to the carrier. These lines are not equal. In this example the rate of departure is greater than the rate of return. If the airplane returned after 1 hr. in the course out, the time back would be greater than 1 hr.

A formula for finding the time to turn in a radius-of-action problem when the wind is blowing, and the plane is to return to a carrier moving on a constant course at a fixed speed is:

$$T = \frac{bt}{a + b}$$

T = hours and decimal parts of hours
a = rate of departure (rate of going away from the carrier)
b = rate of return
t = available fuel hours (total capacity in hours minus reserve)

The formula can be derived by considering a problem.

Problem:

If the rate of departure from a carrier is 120 m.p.h. and the rate of return is 80 m.p.h. and 4 hr. are available for the trip out and back, find the time to turn.

Solution:

If the plane flies 1 hr. out, its time out is, of course, 1. As the plane's returning rate is 80 m.p.h., the time returning after 1 hr.'s flying out to a turning point is greater than 1 hr. The time returning in this case is represented by $\frac{120}{80}$, or the rate out divided by the rate back. The statement $1 + \frac{120}{80}$ represents the time out and back. If we consider the time out to the turning point when the problem is limited to 1 hr. for the whole trip, we get

$$\frac{1}{1+\frac{120}{80}} = \frac{1}{\frac{5}{2}} = \frac{2}{5}$$

or the ratio of the time out to the whole time. The ratio of the time out to the whole time in 1 hr. flying is constant for the conditions stated in the problem. To find the point to turn for 4 hr. available flying time, multiply this ratio by 4. $4 \times \frac{2}{5} = \frac{8}{5}$. T, the time to turn, is therefore 1.6 hr. after leaving the carrier.

In general:

$$a = \text{rate of departure}$$

$$b = \text{rate of return}$$

$$t = \text{time available}$$

After finding the time to turn in hours and decimals, change it to hours and minutes, and add to the time of take-off.

Use the formula for time to turn, to solve these problems. *(Do not write in this book.)*

*Hour of Departure**	*Rate of Departure*	*Rate of Return*	*Flying Hours Available*	*Time to Turn*	*Hour to Turn*
1000	120	75	3		
1200	115	110	4		
1300	135	100	$3\frac{3}{4}$		
0900	95	112	$2\frac{1}{2}$		
0700	125	95	$4\frac{1}{4}$		
2000	122	115	2		
2100	95	85	$1\frac{1}{2}$		
0800	130	105	$2\frac{3}{4}$		
0500	110	98	2		
2200	112	104	3		

* In the army and navy, time is measured from midnight to midnight:
0100 is 1 A.M. 1230 is 12:30 P.M.
0325 is 3:25 A.M. 2100 is 9:00 P.M.

A formula for finding the distance out to the turn is:

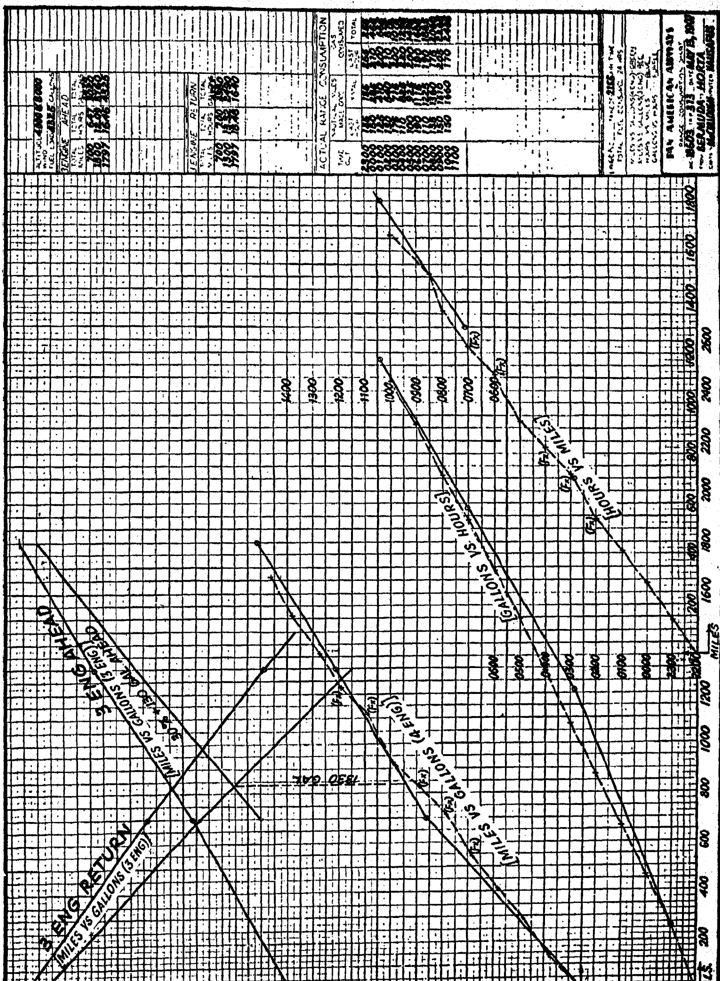
$$D = tg$$

$D =$ distance from point of take-off out to point of turn
$g =$ ground speed on flight out

1. A pilot desires to fly a course 35° at air speed of 120 m.p.h. There is a wind of 20 m.p.h. velocity from 270°. He wishes to return to *B*, which is 50 mi. from *A* at 115°. Draw a diagram, and find the ground speed out, the ground speed back, the heading out and the heading back if the pilot must complete the trip in 1 hr. 45 min. from the time he takes off.

2. A scouting plane sets out on a mission from a carrier steering a constant course 95° at 25 m.p.h. The plane heads 45° and is to maintain an air speed of 120 m.p.h. There is a wind of 15 m.p.h. velocity from 275°. Find the course out, the ground speed out, the course and ground speed back, rate of departure, the rate of return, and the time out to the turn if the plane is to return to the carrier after 2 hr. flying.

3. A plane sets out from *A*, heading 285° at 120 m.p.h. There is a wind of 20 m.p.h. velocity from 95°. The plane is to return to B, which is 80 mi. from *A* at 175°, and maintain an air speed of 115 m.p.h. The plane is to return in 1 hr. 45 min. Find the ground speed out, the ground speed back, rate of departure, rate of return, the time out to the turn and the distance to the turn.



Courtesy, Pan American Airways

The "Howgozit Curve"

This curve gives the crew aloft and the flight watch ashore continuous information as to the fuel reserve aboard the aircraft and the fuel required for completion of the flight to destination or back to the point of departure. There are really five curves: (1) miles vs. gallons, showing normal four-engined fuel consumption for the flight; (2) gallons vs. hours of flying; (3) hours vs. miles; (4) and (5) show three-engined operation for emergencies.

CHAPTER 21

INTERCEPTION

AN OLD navigation rule states that if the bearing of one ship from another is constant, the ships will collide. In Figure 1, B, B_1, B_2, B_3 stand for positions of a ship following the course BC. A, A_1, A_2, A_3 represent positions of a second ship following the course AC. If the lines a, b, c, and d are parallel, the ships following the courses shown will reach C at the same time.

We can think of what it means to keep constant relative bearing if we remember that angles A, A_1, A_2, A_3 are to be equal if this condition is to be fulfilled.

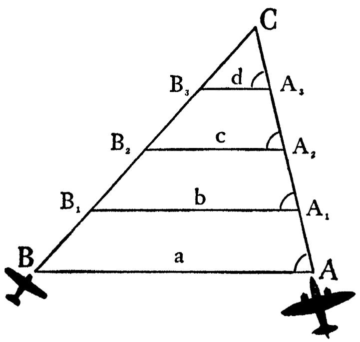


Fig. 1

The method of interception may be used to find the meeting points of two aircraft, of an aircraft and a surface ship, or of two ships. The navy uses this method regularly for the interception of its carriers by airplanes returning to their seagoing hangars. In time of war bombers intercept the enemy fleet, and interceptor planes seek out and destroy enemy bombers.

In general, there are two kinds of interception problems; first, when the aircraft or vessel to be intercepted is visible from the interceptor; second, when the aircraft or vessel to be intercepted cannot be seen from the interceptor, but its position, course, and speed are known.

Interception of craft is possible in the shortest time only when the relative bearing between the approaching craft re-

mains constant. Plotting the relative bearing between the starting positions of the two ships will show whether interception is possible. If the courses are such that they will intersect in the direction of travel, then interception will take place if constant bearing is maintained.

When the craft to be intercepted can be seen from the pursuing plane it is possible to use a visual check to maintain the direction which will give interception in the shortest possible time, provided there is no change in the speed or direction of the craft to be intercepted.

In Figure 2 suppose A and B are located on lines CE and DE as shown. B is directly north of A. Assume that B is traveling at a speed that will enable him to reach E in exactly 30 min. and that A has a speed which will bring him to E at the same time. In this case if the two planes continue, the interception will occur at E, and it will be in the shortest possible time at the speeds being used.

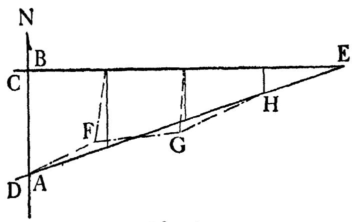


Fig. 2

Suppose that B continues his course and speed and that A is to find and hold the course for interception. If the pilot of A cuts in toward the flight path of B too quickly, he will come out behind B, in a stern chase, and will lose time. If he heads in a direction too nearly parallel to A's course, he will need to turn in to keep from getting too far ahead. He attempts to find the average of these two headings.

He does not know that heading AE will be the proper one, so he heads from A toward F. He notices that the original relative bearing (the direction of B from A) is such that he can sight B over a point on the left wing of his plane. He holds a steady heading until he observes, at point F, that B seems to be pulling out ahead of him. This shows A that he is turning toward the path of B too quickly and that he will have a stern chase if he continues.

At F he swings several degrees to the right, straightens out on another heading and notes the relative position of B. He holds this heading for several minutes, and at G he notices that the position of B seems to be moving to the rear as he con-

tinues. This tells him that the path of his plane is too nearly parallel to that of *B*, and he turns toward the left again.

When *A* finally narrows the change in heading down to a heading on which the relative bearing of *B* remains constant, he will be on the heading which will give interception in the shortest possible time.

In this example *A* required greater air speed than *B*. Whether or not more speed is required in a given situation is determined by the courses followed, the starting positions of the aircraft, and the wind.

An interception problem can be solved before the target (the plane or ship to be intercepted) is in sight. A problem of this kind can be solved when the location, direction of travel, and speed of the target are known, as well as the interceptor's air speed and the wind velocity.

Example I:

B is 60 mi. north of 32 mi. west of *A*. A plane leaves *A* and flies due east at 110 m.p.h. A plane with an air speed of 140 m.p.h. leaves *B* at the same time to overtake the first plane. There is no wind. Find the heading the pursuing plane should take, the distance from *A* to the point where interception occurs, and the time required for interception.

Solution:

Lay off $AR = 32$ mi. and draw $RB = 60$ mi. at right angles to *AR*. Draw *AB*. Measure *AC* on *RP* to represent *A's* air speed of 110 m.p.h. With *B* as a center and with a radius representing *B's* air speed of 140 m.p.h. draw an arc cutting *CE* at *F*. Draw *BF* and extend *BF* to *P*, the point of interception. (*CE* was drawn parallel to *AB*.) *BP* represents *B's* distance for interception. *BP* is found to be $115\frac{1}{2}$ mi.

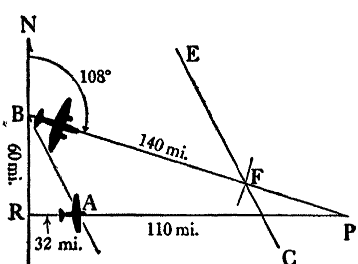


Fig. 3

The following proportion can be used to determine *t*.

$$\frac{115\frac{1}{2}}{140} = \frac{t}{60}$$

The times here are proportional to the distances traveled.

By drawing *CE* parallel to *AB* and finding the point *F* on

CE so that BF represents 1 hr. flying for B, we fixed the condition of constant bearing between the planes for 1 hr. flight for each. By continuing BF to P we find the point of interception if the planes continued beyond C and F so as to maintain this constant bearing.

We have noticed that in triangle ABP, FC is parallel to the base AB. Instead of starting with a triangle we started with the base AB of what grew into a triangle as we moved AB along the transversals which are the two courses, always keeping the new position of AB parallel to its original position, until we arrived at the point C, where the distance between the planes is 0.

The known conditions in the problem, if plotted as lines, determine a trapezoid. The bases of this trapezoid are two constant bearing lines, and the nonparallel sides are the courses and ground speeds of the planes. By extending the nonparallel sides of the trapezoid we obtain the triangle whose vertex is the point of interception. The sides of the triangle formed represent the distances from the starting points as well as the courses of the planes. The segments of the course lines between any two consecutive constant bearing lines, if these parallels are at 1 hr. intervals, give us the ground speeds of the planes. The description of the problem applies to the condition of no wind. Later we shall consider the same type of problem when the wind is blowing.

Note: All distances in these problems are in nautical miles. All speeds are in knots. All problems in this section are for the condition of no wind.

Problem:

1. After a destroyer has been under way for 5 hr. from A, a Vought-Sikersky takes off from a base B, 50 mi. and 130° from A, to overtake the destroyer. The plane travels at 110 knots and the destroyer's speed is 25 knots. The destroyer's course is 73°. Find the destroyer's distance from A to the point of interception, the time the plane takes for interception and the plane's required course.

Solution:

Locate A on the N-S line. Draw a line from A at 130°, and locate B 50 mi. from A on this line. Draw a line from A at 73°

representing the destroyer's course. Measure 5 hr. time at 25 knots, or 125 knots, on this line. The destroyer is now located at S. Find T 1 hr. course for the destroyer beyond S. Through T draw TC parallel to SB. With B as a center and with a radius representing 110 knots draw an arc cutting CT at R. BR is 1 hr. ground speed for the plane. Extend BR to P, the point of interception. AP is the distance from the starting point of the destroyer to the point of interception and is found to be nearly 164 mi. The $\angle$NBP = 56° is the plane's course. The time for the plane to intercept is found by substituting in

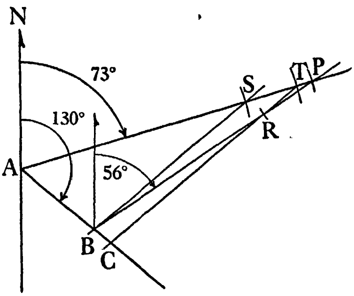


Fig. 4

$$\frac{SP}{ST} = \frac{t}{60} \cdot \frac{39}{25} = \frac{t}{60}. \quad t = 93.6 \text{ min.}$$

BP represents the shortest possible course for the plane to take for interception under the conditions of the problem.

If the plane traveled at a much faster rate than that given in the problem, interception would take place in less than 1 hr. In this case the arc with BR as a radius, representing the interceptor's air speed, would cut the second constant bearing line extended beyond the destroyer's course, as illustrated.

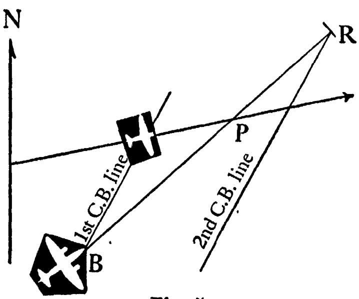


Fig. 5

2. An enemy plane is reported flying over B at 82° and 112 knots. Ten minutes after receiving this news an interceptor takes off from A, which is 10 mi. at 185° from B. What must A's air speed be in order to overtake the plane in $1\frac{1}{4}$ hr.?

3. Find A's course in problem 2 and the enemy plane's distance from B when intercepted.

4. A ship left A, steaming at 20 knots at 1000 hour on course 95°. Five hours later a coast-guard plane left B, which is 50 mi.

at 190° from A, to intercept the ship. Find the time at which interception occurred.

5. Find the plane's course in problem 4 and the distance the ship traveled between the time the plane took off and the time it was intercepted.

6. A group of fighters left airfield A at 0900 hour, traveling at 110 knots on a course 275°. After 10 min. a second group took off from airfield B, 15 mi. and 35° from A. At what rate of speed will the planes from B need to fly in order to intercept the first group at 0945 hour?

7. A task force consisting of battleships, cruisers, and destroyers set out from base A at 2100 hour. At 2130 hour a carrier set out from base B, 42 mi. and 110° from A. The task force steams at 18 knots course 185°. How long will it take the carrier steaming at 25 knots to overtake the force?

8. Find the carrier's course in problem 7 and the distance from A to the point of joining the force.

9. An airplane carrier is steaming at 25 knots on course 85°. After 3 hr. a plane sets out from A, located 35 mi. and 190° from B, the starting point of the carrier in this problem. How long will it take the plane flying at 110 knots to intercept the carrier?

10. A ship leaves port A at 0800 hour and steams 80° at 18 knots. After the ship has been under way on this course for 6 hr., a plane leaves B, which is 25 mi. and 280° from A, and flies at 110 knots to intercept the ship. At what time will interception take place?

11. Find the course of the plane in problem 10 and the distance of the point of interception from A.

12. An enemy submarine is reported on a course 110° making 15 knots. Twenty minutes after the report is received a blimp sets out from a station 50 mi. and 185° from the first reported position of the submarine. How long will it take the blimp to intercept the submarine's course if the blimp's air speed is 55 knots?

13. Find the course of the blimp in problem 12.

14. A ship is making good a course 35° at 20 knots from A. Another ship sets out from B, 35 mi. due south of A and 1 hr. after the first ship left A, to intercept the first ship. The speed

of the second ship is 25 knots. Find the time for the second ship to overtake the first.

15. Find the course of the second ship in problem 14.

It is reported that an aircraft is over B at 0900 hr. and is making good the course BM at a known ground speed. The interceptor is at A. Locate the interceptor's position A on the N-S line and draw the course BM of the other aircraft.

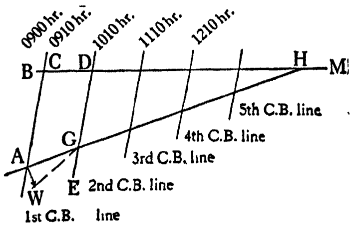


Fig. 6

A can take off at 0910 hr. Locate the point C on BM which will be B's position when A takes off.

Draw a line through A and C and label it the first CB line (first constant bearing line).

The position of D is determined, so that CD equals 1 hr. of the target's travel along his own course. Draw ED through D parallel to AC and label this line the second constant bearing line.

From A draw AW equal to 1 hr. wind downwind. From W locate the point G on the second constant bearing line CB so that WG equals 1 hr. of the interceptor's air speed.

Draw a line from A through G and extend it until it intersects the line $BCDM$ at H.

Point H will be the point of interception, AGH will be the interceptor's course out, and the direction of WG will be the heading out.

The time of interception can be found as follows:

$$\frac{CH}{CD} = \frac{t}{60}$$

The distance CH is to the distance DC as the time required is to 1 hr.

The interceptor's speed may also be used to find the required time.

$$\frac{AH}{AG} = \frac{t}{60}$$

There is still another method of finding the time required. This is called the *rate-of-closure method.*

In the example already described the distance AC minus the distance GD gives the rate of closure R/C. $R/C = AC - GD$. After the rate of closure has been found, the distance AC is divided by the rate of closure to give the time required to intercept. In Figure 7, the time will be $\frac{AC}{AC - GD}$. The result will be in hours and fractions of hours.

The advantage of the rate-of-closure method over the other two methods is that only the first and second lines of constant bearing are required and a much larger scale can be used in the construction, thus making for greater accuracy.

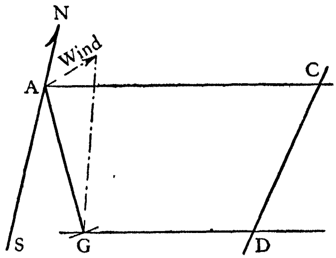


Fig. 7

$ACDG$ in Figure 7 might be called the trapezoid of closure. The bases of the trapezoid are two constant bearing lines, and the sides AG and CD are the courses and ground speeds of the planes. If interception takes place in less than 1 hr., the formula for time of closure becomes $\frac{AC}{AC + DG}$. Draw a figure for this condition of interception and explain why we add AC and DG in this case.

1. Find the time required for an interceptor to close in on an enemy plane if the first constant bearing line is 25.6 mi. and the constant bearing line after 1 hr. of pursuit is 15.7 mi.

2. A ship sets out from New York at 0700 hour on a course 95° at 21 knots, and 5 hr. later a plane starts from an airport 23 mi. and 85° from New York to overtake the ship. The plane's air speed is 104 knots. There is a wind of 20 mi. velocity from 225°. Find the plane's ground speed.

3. Find the time for interception in problem 2 and the plane's course.

4. A ship is steaming at 20 knots on a course 125°. A plane located 50 mi. and 155° from the ship's reported position starts pursuit 15 min. after the position of the ship is reported. The plane's air speed is 105 knots, and there is a wind of 15 mi.

velocity from 180°. Find the plane's ground speed and course.

5. Find the distance from the point where the ship was first reported to the point of interception.

6. Find the time required for a plane flying at 125 knots to overtake a destroyer steaming at 27 knots on a course 35° if the plane takes off 5 hr. after the destroyer left *A*, which is 35 mi. northwest of the airport from which the destroyer set out. There is a wind of 27 mi. velocity from 180°.

7. A constant bearing line between two units of the fleet that are to form a single force is 18 mi. long. The constant bearing line after 2 hr. more of steaming is 14.5 mi. in length. How long will it take the units to meet?

8. A carrier passes location *A* at 0930 hour, steaming 25 knots on a course 185°. At 1200 hour a plane starts from a point 60 mi. and 135° from *A* to overtake the carrier. The plane's speed is 130 knots. There is a wind of 15 mi. velocity from 255°. At what time will the plane be over the carrier?

9. What are the plane's course and ground speed in problem 8?

10. Find the time required for interception under the following conditions: A ship is steaming on a course 22° at 20 knots. The constant bearing line from a plane to the ship at 0800 hour is 85 mi. at 80°. The speed of the plane is 110 knots.

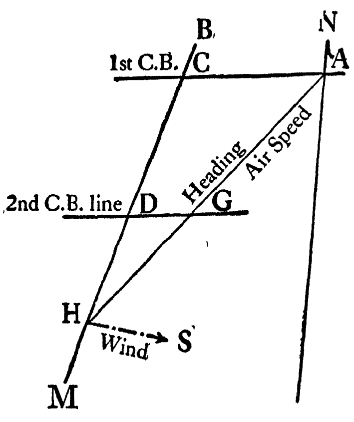


Fig. 8

Interception when wind acting on both is the same. (See Fig. 8.) Mark the position *C* of the objective at the instant the interceptor plans to start from *A*.

Draw the target plane's heading and air speed as the line *BM*. Make *CD* equal to his air distance traveled in 1 hr. This is the target plane's air speed. Draw the first and second constant bearing lines as usual. From *A* as a center draw an arc equal to the air speed of the interceptor. This arc cuts the second bearing line at *G*.

Draw AG and extend it through G to intersect BM at H. H is the point of interception with reference to the air. It is the position for the no-wind condition of interception.

The wind affects both planes by the amount of time involved multiplied by the velocity of the wind. If the wind were blowing in the direction from H to S and the distance HS represents the wind speed times the time interval of the flight, then the actual interception in relation to the ground would be at S. A straight line from A to S would represent the actual course out.

If a change of data occurs after take-off, the problem must be reworked as a new problem. Use the time, the position of the interceptor when he can change his course, and the position of the target at this same time for the first new constant bearing line. Then the second new constant bearing line will be parallel to the first new constant bearing line and will be 1 hr. of the target's travel on his new course. The rest of the problem can be worked as already described.

1. A plane is flying a course 175° at 110 m.p.h. The pilot of an interceptor, flying at 150 m.p.h. knows that a constant bearing line is 25 mi. long at 90° from his position. There is a wind of 20 m.p.h. velocity from 260°. Find the time for interception from the constant bearing line described.

2. Locate the point of interception in problem 1.

3. A plane flies over A at 1300 hour on a heading 25° at 115 m.p.h. air speed. Ten minutes later another plane leaves B, which is 30 mi. west of A, at 130 m.p.h. to join the first plane. There is a wind of 15 m.p.h. velocity from 310°. Locate the point of interception and find the time required by the interceptor.

4. Find the ground speed of both planes in problem 3.

5. Solve problem 3 for the following conditions: air speed and heading of first plane the same, but wind of 20 m.p.h. velocity from 95°.

6. A plane's heading is 95° and air speed 120 m.p.h. and is to be intercepted by a plane flying at 135 m.p.h. air speed.

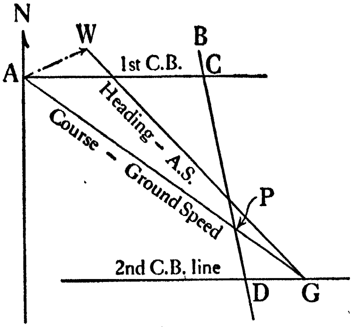


Fig. 9

This diagram illustrates interception in less than an hour when the wind is blowing. The first and second constant bearing lines are one hour's flying apart. The course-ground-speed line of the interceptor crosses the course line of the ship at *P*.

The interceptor's position on a constant bearing line is at 185° and 25 mi. from *A*. There is a wind of 20 m.p.h. velocity from 25°. Locate the point of interception.

7. Solve problem 6 for the same conditions except that wind is from 330° at 15 m.p.h. velocity.

8. *A*'s air speed is 120 m.p.h. His heading is 155°. At the same time *B*'s air speed is 130 m.p.h. at a point 265° and 20 mi. from *A*. There is a wind of 10 m.p.h. velocity. Find the point of interception if *B* is to overtake *A* in the shortest possible time.

CHAPTER 22

MISCELLANEOUS

1. The following thicknesses of sheet metal have been measured by caliper. Change these measurements to the nearest 32nd of an inch: 0.875, 0.8437, 0.7812, 0.7187.

2. How many circular disks each 3 in. in diameter can be cut from a piece of aluminum alloy 8 in. by 10 in.? What is the area of metal wasted? Make a drawing.

3. From the data given below find the cost of 115 ft. of item A and 140 ft. of item B and 65 ft. of item C.

	Inside Diameter inches	*Weight per 100 ft.*	*Cost per 25 ft.*
A	$\frac{1}{8}$	3.8	$0.85
B	$\frac{3}{16}$	6.5	1.10
C	$\frac{7}{16}$	17.1	2.65

4. If the scale of a map is 15 mi. to the inch, what is the actual distance between two towns if they are 4.2 in. apart? What are the following map distances in miles: 3.7 in., 10.2 in., 8.1 in., 9.5 in.?

5. An article stated that in 1940 13,000,000 lb. of air mail were transported in the United States. This was an increase of 1,600% since 1926. How many pounds were transported in 1926?

6. At one time the air-mail rate was 5 c. for each ounce or fraction thereof and 10 c. for each additional ounce. The present air-mail rate is 6 c. per ounce and fraction thereof. How much more postage would be required at the old rates than at the present rates for air-mail items weighing 6 oz., 7 oz., 9 oz., 10 oz., and 15 oz.?

7. A Curtiss-Wright-20 has a 5,200 lb. capacity for mail and express. Could one of these planes take all of the items in the list below? Is there a reserve capacity? If so, how much?

Bags of Mail

No. of Items	Weight per Bag pounds
2	160
3	150
1	125
2	164
3	75
5	110
1	62
5	140

Express Packages

No.	Weight per Bag pounds
1	110
1	237
1	35
1	69
2	75
3	16
6	125

8. For the upkeep of a medium-sized plane the cost might be \$30 a month plus 3 c. per mile. Find the cost of upkeep for 5 mo. and 8,000 mi., for 4 mo. and 6,500 mi.

9. Fare in excess of 40 lb. per passenger is charged at the rate of $\frac{1}{2}$ of 1% of the published one-way fare per pound. A passenger's baggage weighs 55 lb., and the one-way fare is \$88.80. What is the excess-baggage charge?

Find the excess-baggage charge from data:

Weight of Baggage pounds	One-Way Fare
42	\$12.80
60	59.05
52	95.30
48	50.20

10. In their first flight the Wright brothers used a 4-cylinder 12-horsepower engine weighing 144 lb. If a modern engine had the same weight per horsepower, what would an engine of 1,250 H.P. weigh? Some modern engines have a weight of 1.08 times the horsepower. Using this ratio, find the actual weight of a modern engine of 1,425 H.P.

11. The weight of fabric used in airplane construction must be between 4 oz. and 4.5 oz. per yard. What is the weight of 50 yd. of fabric of average weight?

12. For model aircraft the wing loading must be 15 g. per square decimeter. Test each of these models to determine if it meets the minimum requirements.

	Gross Weight grams	*Wing Area square decimeters*
A	1400	80
B	1675	75
C	2340	90

13. The average airway mileage from New York to Lisbon via Bermuda is 3,896. If a clipper used 4,800 gal. of gasoline to complete that flight, what was the average rate of use of gasoline per mile?

14. In servicing a transport plane it was found that 300 gal. of gasoline and 23 qt. of lubricating oil were required. If the price of the gas is $0.21 a gal. and the bill for gas and oil is $69.90, what is the cost per gallon of the oil.

15. The cost of operating a "Cub" trainer is estimated as follows:

Gasoline $3\frac{1}{2}$ gal. per hr. at	$0.22 a gal.
Oil	0.10
Maintenance	0.20
Hangar	0.10

What would be the cost of operating this trainer for 5 hr.?

16. The weight per 100 ft. of navy specification aluminum-alloy tubing of $\frac{3}{8}$ in. outside diameter is 0.040 lb. How much will 35 ft. of this tubing weigh?

17. The weight per foot of fire-resisting hose of $\frac{1}{4}$ in. inside diameter is 2.4 oz. per foot. What is the weight of 25 yd. of this hose? What is the cost at $0.80 per foot?

18. In painting the airway markers in Oklahoma engineers devised a new system that saved 63% of the $34,269 allotted for the work. How much did the project cost, and what was the saving?

19. The average plane, in case of engine failure, will glide 1 mi. for every 1,000 ft. under calm-weather conditions. How far will a plane, with the engine dead, glide from an altitude of 4,000 ft.? 5,250 ft.? 6,000 ft.?

20. For every hour in the air American Airlines spends 16 man-hours on mechanical overhaul and care. How many man-hours are required for the overhaul and care of 15 planes, each in the air an average of 4 hr.?

21. A single Wright Cyclone engine such as is used in a large transport plane costs $8,000. An engine for a Ford V-8 costs $75. How many times the cost of the automobile engine is the cost of the Wright engine?

22. American Airlines used 9,598,000 gal. of gasoline in 1941. If a typical transport plane has a fuel capacity of 822 gal., how many times could its tanks be filled with this amount of gasoline?

23. The weight per square foot of duralumin of 0.025-in. thickness is 0.365 lb. A standard sheet of this particular thickness is 36 in. by 120 in. Find the approximate weight of a standard sheet.

24. Duralumin sheets come in standard sizes of 24 in. by 120 in. The weight per square foot of one particular thickness is 0.144 lb. What is the approximate weight of one standard sheet of this material? What is the weight of a piece of this material 5 in. by 10 in.?

25. A hangar has the following ground-plan dimensions: 170 yd. by 50 yd.; 0.75 of the space is taken up by planes occupying 2,000 sq. ft. each. Find the number of planes (nearest whole number).

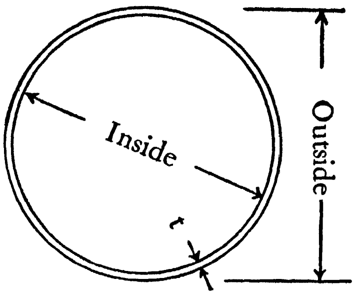
26. What would be the cost of 16 airplane spars 16 ft. long and 6 in. wide and $\frac{3}{4}$ in. thick if the spruce for the spars cost $85 per thousand board feet?

27. The approximate weight per sheet of $\frac{1}{8}$-in. chrome-molybdenum sheet steel is 47 lb. If the standard size of a sheet is 18 in. by 72 in., what is the approximate weight per square foot? At $0.26 per pound what is the cost of 3 sheets?

28. A sheet of dural of a specified thickness weighs .0982 lb. per square foot. What is the weight of a sheet of that thickness whose area is 27.6 sq. ft.? Find the weight of a sheet of this material 10 in. by 60 in. by 9 in.

29. A typical analysis of wrought iron would show iron 99.6%, carbon 0.1%, and other impurities 0.3%. How many pounds of other impurities are there in a ton of wrought iron? how many pounds of carbon?

30. Aluminum-alloy tubing made in accordance with Army and Navy specifications for fuel and oil lines has an outside diameter of $\frac{1}{4}$ in. and a wall thickness of 0.032 in. Find the inside diameter to the nearest thousandth.



31. An aircraft carrier is steaming 90° at 28 m.p.h. If there is no wind, what is the radius of action of a plane of 160 m.p.h. air speed and 4 hr. flying time scouting a course in direction 65°? What is the heading of the return course?

32. Supply the missing values in the following table. *(Do not write in this book.)*

Outside Diameter inches	*Inside Diameter inches*	*Thickness inches*
3.146		0.19
2.66	2.92	
	3.04	0.23
4.28	4.02	
4.62	0.31	

33. Two planes leave an airport at the same time, one flying north at rate of 140 m.p.h. and the other east at rate of 150 m.p.h. How far apart will the planes be at the end of 4 hr.? (No wind.)

34. Find the horizontal distance traveled from starting point in 1 min. for each plane. (Conditions given are for still air.)

Plane	*Air Speed m.p.h.*	*Climb feet per minute*
A	65	800
B	70	750
C	60	650
D	50	520

35. A plane heading eastward from *A* and making 130 m.p.h. air speed is acted upon by a wind of velocity of 25 m.p.h. from 330°. Using graph paper, figure the ground speed by making a scale drawing.

36. A plane heading 12° is acted upon by wind with velocity

of 32 m.p.h. from 180°. If the plane is making air speed of 145 m.p.h., find the ground speed.

37. A plane heading north at the rate of 125 m.p.h. is acted upon by a west wind of velocity of 30 m.p.h. Construct the vector diagram and figure the distance *AB* the plane will have gone over the ground in 1 hr.

38. A plane's track is in the direction 30°. If the plane covers 135 m.p.h., find eastward and northward components of this velocity.

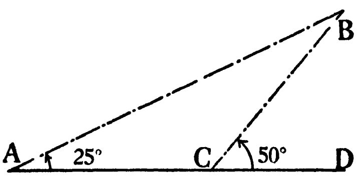
39. A carrier is steaming northeast at a speed of 27 knots. Find the northern and eastern components of its velocity.

40. A navy blimp has a speed of 55 m.p.h. and is heading 180°. The wind is blowing 135° with a velocity of 30 m.p.h. Find the distance the blimp travels in 1 hr. and its direction.

41. Suppose the blimp is heading 275° and the wind is blowing 283° with a 40 m.p.h. velocity. Find the distance covered by the blimp in 1 hr. and its direction.

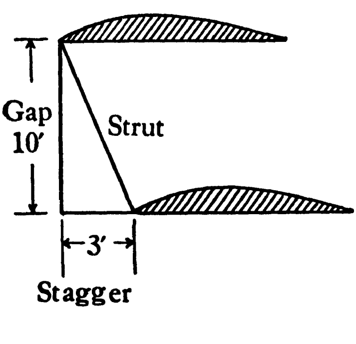
42. A plane's track is in the direction 135°. Its ground speed is 124 m.p.h. Find the eastward and southward components.

43. A plane heading east at air speed of 140 m.p.h. is acted upon by a north wind of velocity 40 m.p.h. Construct the vector diagram and figure the distance the plane will have gone over the ground in 1 hr.



44. A carrier is proceeding along the course *AD*. It is observed that the $\angle BAC$ is 25°. The quartermaster checks the angle of the course with the lighthouse at *B* and observes that $\angle BCD$ is 50°. If the carrier is proceeding at 20 m.p.h. and takes 25 min. to go from *A* to *C*, how far is the carrier from the lighthouse when at *C*?

45. Find the strut length if the gap is 10 ft. and the stagger 3 ft. Find the strut length if the gap is 12 ft. and the stagger 4 ft. Find the stagger if the strut is 16 ft. and the gap 11 ft.



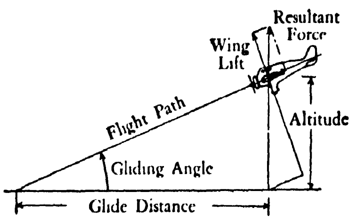
46. The air speed of a plane 150 m.p.h., course to make good, 87°, wind is from 175° at 20 m.p.h. Find the heading and ground speed.

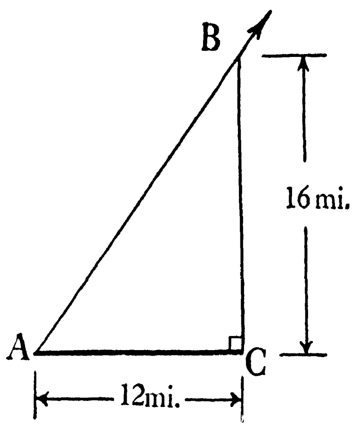
47. A plane leaves Newark with a 5-hr. supply of gasoline. The course is 260° to another airport 472 mi. distant. The air speed is 115 m.p.h. and there is no wind. Circumstances force the pilot to select another airport. At what distance from Newark must he change course to reach this alternate airport if the second airport is 330° and 100 mi. from Newark?

48. A plane is to leave airport *B* to overtake a vessel that has sailed from port *A* at 3:00 P.M. at 25 m.p.h. It is planned to have the plane overtake the vessel in just 6 hr. If the plane flies at rate of 140 m.p.h., figure how far the plane will fly. With a scaled radius draw an arc cutting the course of the vessel (using *B* as a center). *B* is 35 mi. from *A* and due south of *A*. The ship is sailing 90°.

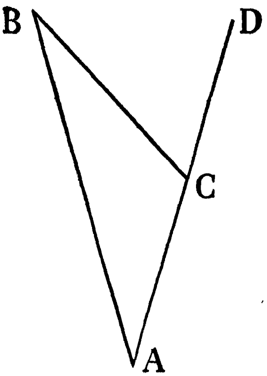
49. $$\frac{\text{glide distance}}{\text{altitude}} = \frac{\text{lift}}{\text{drag}}$$

If $\frac{l}{d} = 10$ and the glide distance is 2 mi., find the altitude.





50. From the data given in the diagram at the left, determine $\angle A$.



51. If AD represents a course, and $\angle BCD = 2 \angle BAC$, what is known about BC?

52. Find length of AB and $\angle A$.

53. Using graph paper, construct a diagram and find AC in the diagram below. The wind is from 90°.

54. To find the length of a strut supporting a wing use the formula:

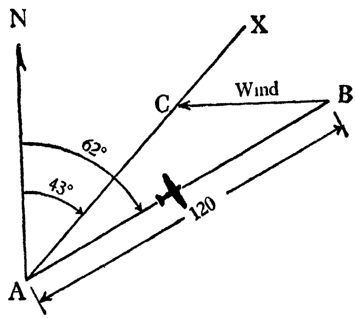
$$s \doteq \sqrt{m^2 + n^2 + r^2}$$

$m =$ the dimension parallel to the fuselage axis

$n =$ the dimension parallel to the wing axis

$r =$ the dimension in a vertical direction

Find s when $m = 8$ in., $n = 92$ in., and $r = 30$ in.



55. The Post Office Department has a special rate of 5 c. per pound for books sent by air mail to certain South and Central American points. Find the cost of sending a shipment of books weighing 35 lb. to Rio de Janeiro and compare this cost with that of sending the shipment by International Air Express from Miami. (See chapter on Air Express.)

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Civil Pilot Training Manual, 1941, 334 p. (Civil Aeronautics Bulletin No. 23)

Practical Air Navigation, by Thoburn C. Lyon, 1940, 245 p. (Civil Aeronautics Bulletin No. 24)

Aerodynamics for Pilots, by Bradley Jones, 1940, 158 p. (Civil Aeronautics Bulletin No. 26)

U.S. Navy Hydrographic Office Bulletin No. 216.

U.S. War Department, War Department Technical *Air Navigation* Manual No. TM-205, U.S. War Department, Washington, D.C., 1940.

YANCEY, LEWIS A., *Aerial Navigation and Meteorology,* Henley, New York, 1929, 316 p.

Young America's Aviation Annual, McBride, New York, 1941, 2 Vol.

ZIER, AVRUM, *Aerodynamics for Model Aircraft,* Dodd, Mead, New York, 1942.

SUGGESTED FILMS

Key to Film Annotations

Aerodynamics; Theory of Flight. Erpi Classroom Films, 1941; sd.—11 min. —16 mm., 35 mm. (Sale: Erpi, 16 mm. $50, 35 mm. $100. Rent: Cal, Geo, Ind, IoS, Kan, Ken, Ohio, Wis, YMCA)

Aerodynamics; Theory of Flight.—Title
Erpi Classroom Films—Producer
1941—Date of production
sd.—sound film: si.—silent film
11 min.—11 minutes' screening time
16 mm., 35 mm.—16 and 35 millimeter film
(Sale: Erpi and others—A list of film distributors, identified by the abbreviations, directly follows the film annotations.)

Aerodynamics; Theory of Flight. Erpi Classroom Films, 1941; sd.—11 min.—16 mm., 35 mm. (Sale: Erpi, 16 mm. $50, 35 mm. $100. Rent: Col, Geo, Ind, IoS, Kan, Ken, Ohio, Wis, YMCA.) Photography, diagrams, sound, commentary excellent. Study guide available.

The film gives a general idea of the basic principles of aerodynamics by explaining and illustrating, with straight photography and animated diagrams of plain and cambered airfoils in a smoke tunnel, the lift and drag forces affecting a plane in flight. The motions of a plane caused by these forces and

the method of controlling a plane about vertical, lateral, and longitudinal axes with the rudder, elevator, and ailerons is demonstrated. Animation, superimposed on scenes of a model plane in flight, gives a graphic illustration of pitching, rolling, and yawing.

Aerodynamics; Problems of Flight. Erpi Classroom Films, 1941; sd.—11 min.—16 mm., 35 mm. (Sale: Erpi, 16 mm. $50, 35 mm. $100. Rent: Col, Geo, Ind, IoS, Kan, Ken, Ohio, Wis., YMCA.) Photography, diagrams, sound, commentary excellent. Study guide available.

Film shows how an airplane pilot determines the movements of an airplane (taking-off, climbing, banking, stalling, spinning and recovery, diving, gliding, landing) by operating the plane's controls (rudder, elevators, ailerons, stabilizer fin); and demonstrates how these controls regulate the forces acting upon the plane in flight.

Air Currents and How They Behave. Pathé News, 1937; sd.—12 min.—16 mm. (Sale: Gut, $27. Rent: Gut, $1.50; B&H, Cine, IdP, VES, YMCA.) Excellent diagrams. Photography and sound fair.

Part I. Clarence Chamberlin explains device for observing and photographing air currents. Obstacles are suspended in the wind tunnel to show the action of air currents flowing past surfaces with different shapes. Miniature airplane wing in tunnel illustrates forces which keep an airplane in the air and which cause a plane to stall and to go into a tailspin.

Part II. Norman Bel Geddes demonstrates how knowledge of aerodynamics is applied to the streamlining of ships.

The Draftsman. Vocational Guidance Films; sd.—12 min.—16 mm. (Rent: VocG.) Photography and commentary good.

Gives brief explanation of the work of the draftsman and of the requirements for his occupation. Employment opportunities in architectural drafting, machine drafting, drafting in the highway department and in the expanding aviation industry are reviewed briefly. The commentary describes the thousands of drawings which are necessary to the production of a new model of aircraft.

Smoke Streams. The Franklin Institute of Philadelphia; si.—30 min.—16 mm. (Sale: Franklin, $150. Rent: Franklin, $10.) Photography excellent, except for scenes of diagrams illustrat-

ing smoke tunnel and pressure graph. Introductory material available.

The film describes the device for showing smoke-stream effects in a special wind tunnel and shows in detail the flow of air streams of varying velocity about models (including standard airfoils), making possible a visualization of the fundamental principles of aerodynamics. The application of Bernoulli's principle for the production of lift is demonstrated. Air flow over the rotating cylinder, the flat plate, the curved plate, the bird wing section, and three different airfoil sections shows relation of shape of body and angle of attack to pressure and turbulence. Characteristic disturbances in the wake of airfoils of different shapes (the flat plate, the wedge—point forward and point aft, the cylinder, the lenticular section, the NACA cowling, and the streamline shape) illustrate clearly principles of drag.

Reel 2 shows the effect upon stalling point of such high lift devices as the leading edge slot, the split flap, the Fowler flap, the slotted flap, the deflector plate flap, the built-in slot, and the trailing edge flap. Variations in wake flow produced by changing the wing-flap position and changing the shape of the wing tip is demonstrated. Concluding scenes illustrating miscellaneous air-flow phenomena (flow over mountain, flow over building, flow over sailboat) show allied applications of aerodynamics.

FILM STRIPS

The Jam Handy Organization, 1775 Broadway, New York, New York

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Kit I

Aircraft Regulations: Need for centralized regulation. Types, classes and limitations of aircraft certificates. Aircraft logs and records.

Radio and Control: The use of radio and other means of controlling the flow of traffic around airports.

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Stability: Static and dynamic stability. Latèral, longitudinal, and directional stability.
Wing Forces: Lift, weight, thrust and drag acting on the airplane. Balance. Control surfaces.

Kit III

Air Pilotage: The face of the earth. Maps and charts. Pilotage.
Dead Reckoning: True course measurement. Variation, deviation, drift. Plotting the complete course. Use of formulas.
Flight Instruments: Principles of operation. Correction and use.
Pilot Problems: Practical examples of navigation problems and how to solve them. Review of formulas.
Weather: Clouds. Storms. Basic forecasting. The weather map. Weather reports. The importance of weather to the pilot.

Society for Visual Education, 100 East Ohio Street,
Chicago, Illinois

THEORY OF FLIGHT SERIES

I. The Airfoil
II. The Complete Airplane
III. Control of Plane
IV. Stability and Performance

UNITED STATES ARMY SIGNAL CORPS FILMS

The following sound films (available in 16 mm. and 35 mm. sizes) have been produced by the United States Army Signal Corps. They may be secured by applying to the United States Army Signal Corps, Washington, D.C. Arrangements are being planned for distribution, but no guarantee is made of availability.

A list of publications for training, including training films and film strips, may be purchased from the Superintendent of Documents, Washington, D.C.

Film No. 1-160 *Aerodynamics: Air flow.* (18 min.)

Visible air flow in a wind tunnel over airfoils of different shapes is shown. Illustrates relation of shape of airfoil and angle of attack to lift and drag forces, turbulence, pressure

gradient, stall angle. Useful after basic instruction in airfoil design.

Film No. 1-161 *Aerodynamics: Forces acting on an airfoil.* (26 min.)

Different airfoil shapes are illustrated and lift and drag forces in relation to angle of attack are explained by diagrams. Detailed section on wind tunnel and use of monometer to test air forces at various points along the airfoil at positive and negative angles of attack.

Film No. 1-211 *Airplane Structures: Structural units, materials, and loads for which designed.* (8 min.)

Film shows various types of airplane structural units. It serves as an introduction to a series of films covering detailed construction of wings, fuselage, control surfaces, and landing gear.

Film No. 1-212. *Airplane Structures: Wing construction.* (11 min.)

Discloses details of type wing construction in photographs and diagrams.

Film No. 1-312. *Airplane Structures: Static testing.* (12 min.)

This film deals with various methods of testing the static elements of aircraft. It covers such matters as the location of the elastic axis of the wing, torsional testing of the wing, and negative acceleration.

Film No. 1-323 *Airplane Structures.* (20 min.)

Covers process of airplane construction. Explains the importance of drafting, lofting, profiling, shaping, cording, assembling, riveting, and inspecting the airplane during construction. It is a survey film of manufacturing methods not designed to teach these methods but to show types of machines used in airplane manufacture and to explain briefly their purpose and operation.

Film No. 1-245 *Aerial Navigation: Maps and compasses.* (13 min.)

Distortions of maps and illustrated by animated drawings and explained by the commentary. The gnomic projection, the Mercator projection, and the Lambert projection are shown in construction. The compass is pictured with an explanation of the deviation between magnetic north and compass north.

Teaches the fundamentals of maps, compasses, and the proper uses and co-ordination of both.

Film No. 1-328 *Aerial Navigation: Airways flying.* (38 min.)

The film illustrates and explains some of the regulations which have been set up by the Civil Aeronautics Administration to insure safety in air travel. It shows how air traffic is controlled by the green, amber, red, and blue airways systems, and pictures the various methods of communication used between land stations and planes by means of which these controls are affected. Contact flight is demonstrated in some detail; a pilot is shown mapping out a contact flight and using such direction finders as beacons, direction arrows, and geographical landmarks.

Film No. 5-12 *Map Reading.* (43 min.)

Various types of military maps are explained, including strategic, technical, and terrain maps. Distance, true north, magnetic north, agonic line, declination, latitude and longitude, rectangular and polar co-ordinates are explained. Animated drawings and straight photography illustrate elevation, contouring, slope, profiling, and visibility. Explanation of contouring is especially good.

FILM DISTRIBUTORS

B&H	Bell and Howell Filmosound Library 1801-1815 Larchmont Avenue, Chicago, Illinois 30 Rockefeller Plaza, New York, New York 716 North La Brea Avenue, Hollywood, California
Cine	Cinema, Inc. 234 Clarendon Street Boston, Massachusetts
Cal	University of California Extension Division Department of Visual Instruction 301 California Hall Berkeley, California 819 Hillstreet Building 815 South Hill Street Los Angeles, California
Franklin	Franklin Institute of Philadelphia Philadelphia, Pennsylvania

Geo	University System of Georgia Division of General Extension 223 Walton Street, NW Atlanta, Georgia
Gut	Walter O. Gutlohn, Inc. 25 West 45 Street New York, New York
IdP	Ideal Pictures Corporation 28-34 East 8th Street Chicago, Illinois
Ind	Indiana University Extension Division Bloomington, Indiana
IoS	Iowa State College of Agriculture and Mechanic Arts Visual Instruction Service Ames, Iowa
Kan	University of Kansas Bureau of Visual Instruction Lawrence, Kansas
Ken	University of Kentucky Lexington, Kentucky
Ohio	State of Ohio Department of Education Columbus, Ohio
VES	Visual Education Service 131 Clarendon Street Boston, Massachusetts
VocG	Vocational Guidance Films, Inc. 2718 Beaver Avenue Des Moines, Iowa
Wis	University of Wisconsin Madison, Wisconsin
YMCA	Motion Picture Bureau Young Men's Christian Association 347 Madison Avenue, New York, New York 19 South La Salle, Chicago, Illinois 351 Turk Street, San Francisco, California